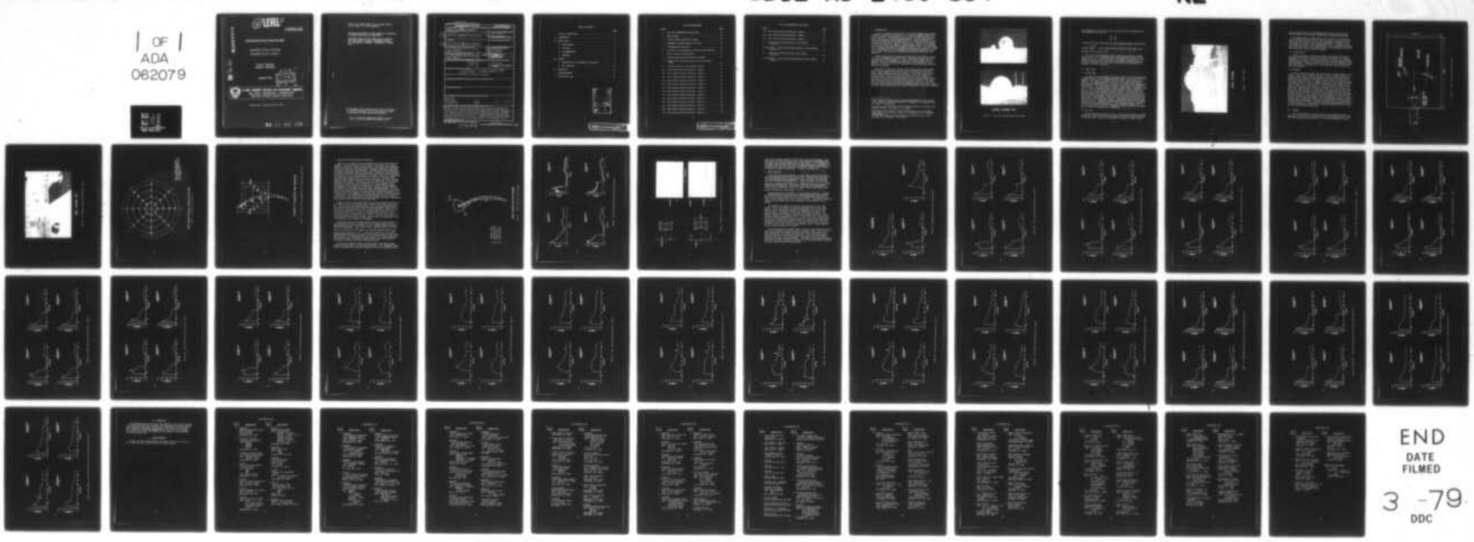
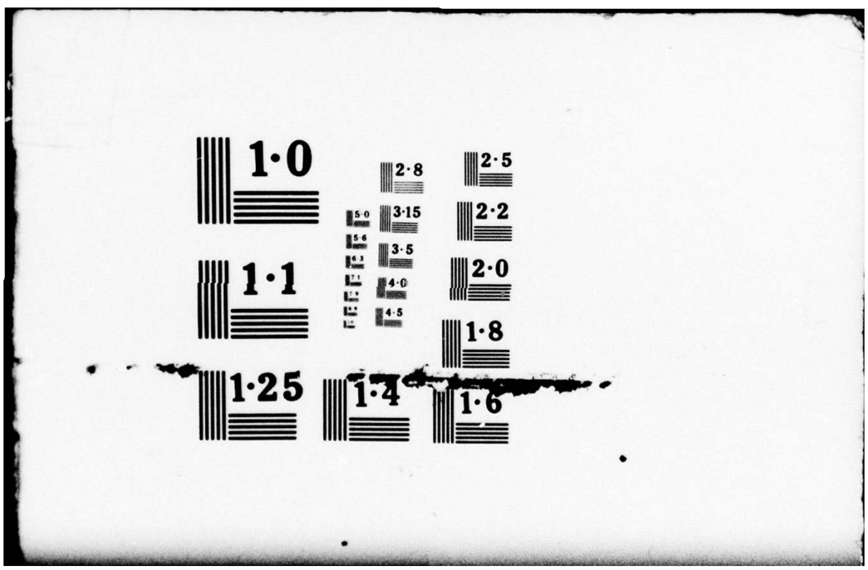
AD-A062 079 ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND ABERD--ETC F/G 19/4
QUARTER SCALE SATCOM ANTENNA BLAST LOADS.(U)
SEP 78 B P BERTRAND, R R ABRAHAMS

UNCLASSIFIED ARBRL-MR-02861 SBIE-AD-E430 134 NL

1 OF 1
ADA
062079



END
DATE
FILMED
3-79
DDC


1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5
5·0
5·6
6·3

(12) B.S. **LEVEL** III

AD-E430 134

MEMORANDUM REPORT ARBRL-MR-02861

QUARTER SCALE SATCOM ANTENNA BLAST LOADS

Brian P. Bertrand
Rodney R. Abrahams

September 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

Approved for public release; distribution unlimited.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
(14) MEMORANDUM REPORT ARBRL-MR-02861

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
(6) QUARTER SCALE SATCOM ANTENNA BLAST LOADS.

5. TYPE OF REPORT & PERIOD COVERED
(9) Final rept.,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) Brian P. Bertrand [redacted] Rodney R. Abrahams

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Army Ballistic Research Laboratory
(ATTN: DRDAR-BLT)
Aberdeen Proving Ground, Maryland 21005

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
(16) 1L162120AH25

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Armament Research & Development Command
U.S. Army Ballistic Research Laboratory
(ATTN: DRDAR-BL)
Aberdeen Proving Ground, Maryland 21005

12. REPORT DATE
(11) SEPT[redacted]R 1[redacted]78

13. NUMBER OF PAGES
53

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(12) 53p.

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
(18) SBIE (19) AD-E430 134

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Blast waves
Shock tubes
Blast loading
Instrumentation

78 11 06 124

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (ljc)

Blast tests that were recently performed on a 2.44 metre SATCOM antenna to determine blast induced strain have been complemented by quarter-scale tests. In these tests, the model antenna was instrumented with pressure transducers to help establish the load to which the full scale antenna had been subjected. The loads determined will be used in the NASTRAN program to calculate blast induced strain in the full scale test. Comparison of predicted with measured strain will be used to assess the applicability of the program for blast hardening designs.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

393 471

LB

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

I. INTRODUCTION

A test was recently performed for the Satellite Communications Agency (SATCOM) to determine the response of a 2.44 metre diameter antenna to blast loading[1,2]. The purpose of the test was to obtain data that could be used for design of blast hardened antennae. The test program used blast waves emerging from the open end of a 2.44 metre shock tube to load the antenna which faced the shock tube exit at a distance of 12 metres, 24° from the centerline, Figure 1. Blast-induced strains on the antenna and free field blast data were obtained during the tests. The antenna was to be returned to SATCOM in its original condition after the tests. Therefore, modifications to it for mounting blast pressure transducers could not be made. The problem of determining actual blast loads then still remained.

SATCOM is interested in obtaining loading data to go with the strain data that was obtained during the tests. Using this loading data with a representation of the antenna in a structural response code, such as NASTRAN, the strains developed with the code can be compared to those measured in the blast tests, and confidence in hardening design using the code can be assessed.

Past tests[3,4] show that the blast wave emerging from an open-ended shock tube has pressure and duration that are functions of the shock tubes' shock overpressure and exit diameter, the distance from the exit and the radial direction from the centerline. They also showed that testing along, or near the extension of the shock tube centerline, is unrealistic for blast simulation because of the jet that emerges from the tube and the ring vortex associated with the jet formation. The tests have shown that close to the exit the distances at which the same blast pressure could be obtained from two different diameter shock tubes firing the same shock overpressures are directly proportional to the exit diameters.

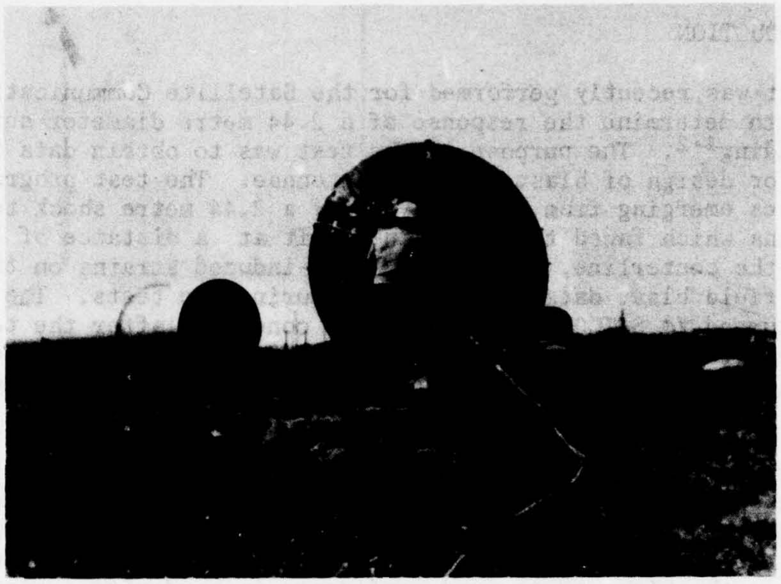
---

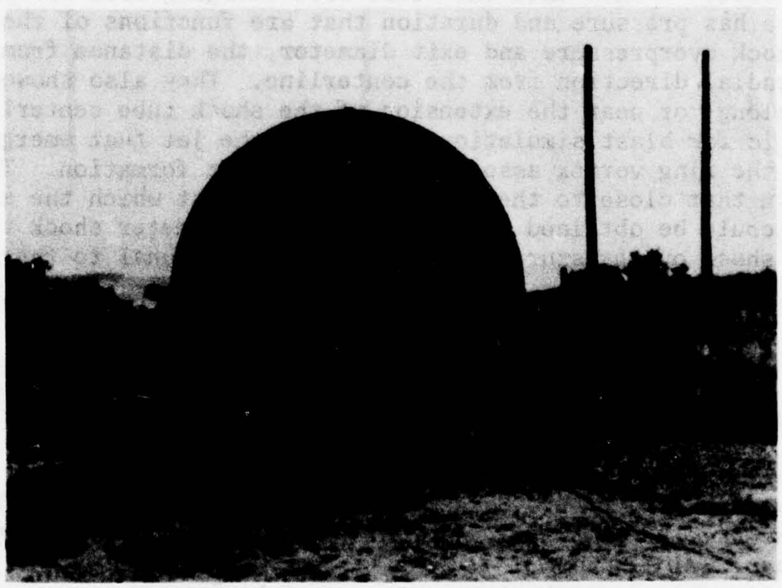
[1] *Blast Loading of a Mobile Satellite Tracking Antenna and of Two Simple Model Antennae, BRL MR 2661, Aug 1976, R. Abrahams, B. P. Bertrand, and R. Pearson.* (AD #A029437)

[2] *Blast Tests of SATCOM AN/TSC-86 Small Terminal Eight-Foot Diameter Dish Antenna, ECOM MR, 1 Apr 1976, R. A. Lechner.*

[3] *Overpressures and Durations of Shock Waves Emerging from Open-Ended Shock Tubes, BRL MR 1724, Nov 1965, B. P. Bertrand and W. T. Matthews.* (AD #633161)

[4] *Proposed Improvement of BRL Dual Shock Tube Facility, BRL TN 1733, Apr 1970, B. P. Bertrand.* (AD #871736)





SATCOM ANTENNA TEST

Figure 1. Full Scale SATCOM Antenna Test Setup

The durations (t) of the blast waves are also directly proportional to exit diameters (d), that is,

$$\frac{t_2}{t_1} = \frac{d_2}{d_1},$$

although past tests[3] have shown that this duration function becomes more like $\frac{t_2}{t_1} = \left(\frac{d_2}{d_1}\right)^{0.6}$ at much larger distances where the free field blast pressure is less than 0.1 kPa.

This linear relationship was used to model the full scale antenna tests, using a 57.5 cm diameter shock tube, and modelling the physical conditions of the full scale test by the diameter ratio, which is 0.24. Pressure transducers were installed in this model to obtain pressure histories from which the blast load on the model will be obtained and related to the full scale case.

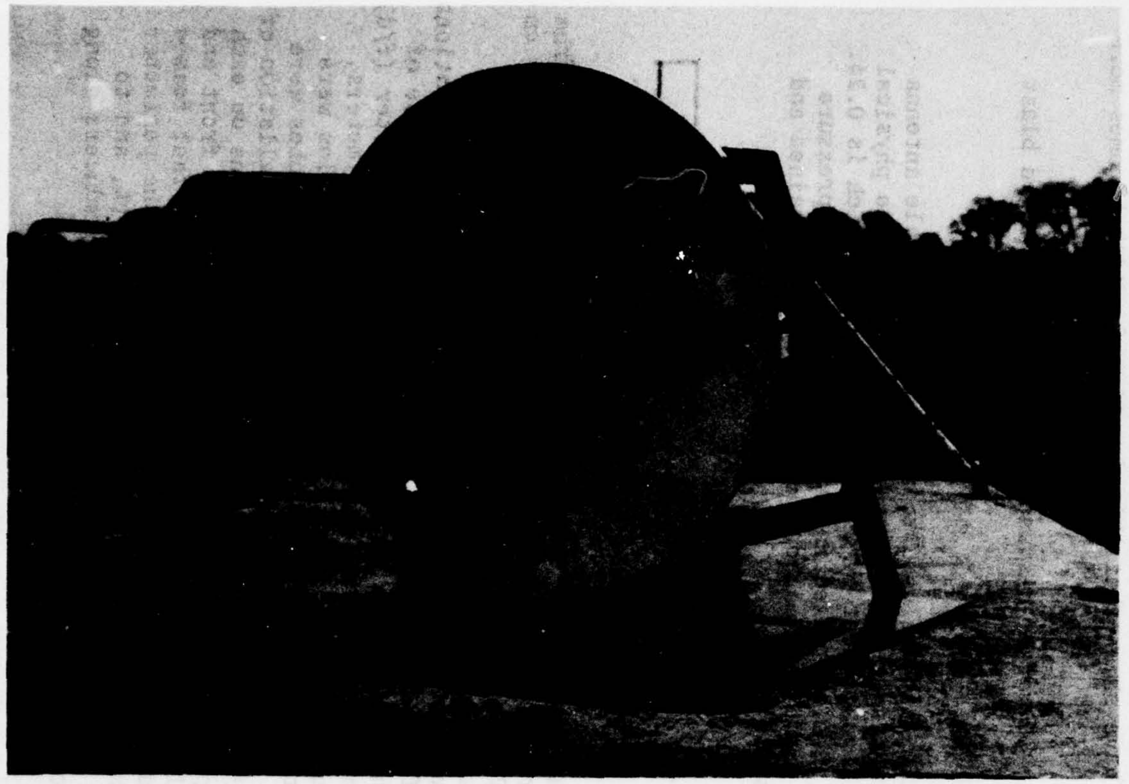
II. MODEL TESTS

A. Antenna Model

The front and rear surfaces of the model antenna were fabricated from two approximately parabolic-shaped aluminum dishes, each having a 58.4 cm diameter, one being 2.5 cm deeper than the other. These dishes were formed in the diaphragm section of the 57.5 cm diameter shock tube by pressurizing aluminum sheets, 1.6 mm thick, until the desired deformations were obtained. The front dish was formed to approximate the surface of the full scale antenna which has a ratio of focal length to diameter (f/d) of 0.3. The two dishes were then welded together at their perimeters, their concave surfaces facing the same direction. Thirteen holes were drilled through front and rear surfaces along 3 radials, and tubes were inserted joining the front and rear surface holes for the installation of blast pressure transducers. This gave four transducer positions on each radial and a center position, Figure 2. The space between the front and rear surfaces was filled with a liquid polyurethane material that foamed rigidly in place. Tabs were welded to the rear surface at the perimeter to facilitate mounting the model to a rigid framework support, and to allow rotation about its axis of symmetry to align the transducers along any of 8 radial directions in 45° increments.

B. Test Area

The area beyond the exit of the 57.5 cm shock tube on which the model antenna was tested was modified to simulate the ground surface beyond the 2.44 m shock tube. This was accomplished by backing a flatbed trailer



MODEL ANTENNA

Figure 2. Model Antenna

up to the shock tube exit and extending one side of the trailer with several sheets of heavy plywood, substantially supported from below.

The antenna model was then placed on this surface at a distance of 2.87 m from the shock tube exit on the 24° radial, its concave surface facing the exit, Figures 3 and 4. This arrangement represents a 0.24 scale model of the full scale SATCOM antenna tests. A pressure transducer mount was placed at the same distance as the antenna from the tube exit on the 24° radial on the opposite side of the centerline so that the free field blast history could be obtained.

C. Instrumentation

Pressure transducers used on the antenna were Endevco Model 8510. These are silicon disc, piezo-resistive strain transducers. A PCBM28 transducer was installed in the shock tube near the exit, and a PCB113A21 transducer was placed in the free field mount. The PCB transducers have quartz elements. Transducer outputs were recorded on tape using a Honeywell 7600 recorder at 80 kHz, FM. A time base and time zero reference were also recorded.

D. Procedure

Pressure transducers were first installed on the front surface of the antenna. There is not complete symmetry in blast loading because the ground surface beneath the antenna delays reflected pressure relief and because of the proximity of one edge of the antenna to the shock tube centerline where the blast is slightly higher. For this reason the model was rotated about its axis of symmetry and gages were relocated as necessary for each shot to assure that the pressure histories along each 45° radial of the surface were recorded. Only one shock wave level in the shock tube, approximately 100 kPa overpressure, was used for these tests. The front center position was used for all the shots on which the front surface was instrumented to assure that the pressure histories were consistent from shot to shot. The front center position was also used when the rear surface was instrumented, with the exception of one shot where the rear center position was used. For that exception, there is a corresponding shot in which the identical rear positions and the front center position were instrumented. It should be noted that a rear location and its opposite front location cannot be instrumented simultaneously because of space limitations. Figures 5 and 6 show the identification and location of the instrumented positions.

III. RESULTS

The shock pressure in the shock tube varied somewhat from shot to shot from a low of 96.5 to a high of 107 kPa, averaging 100.3 kPa. Free field blast pressure varied from 13.2 to 14.8 kPa, averaging 14.0 kPa.

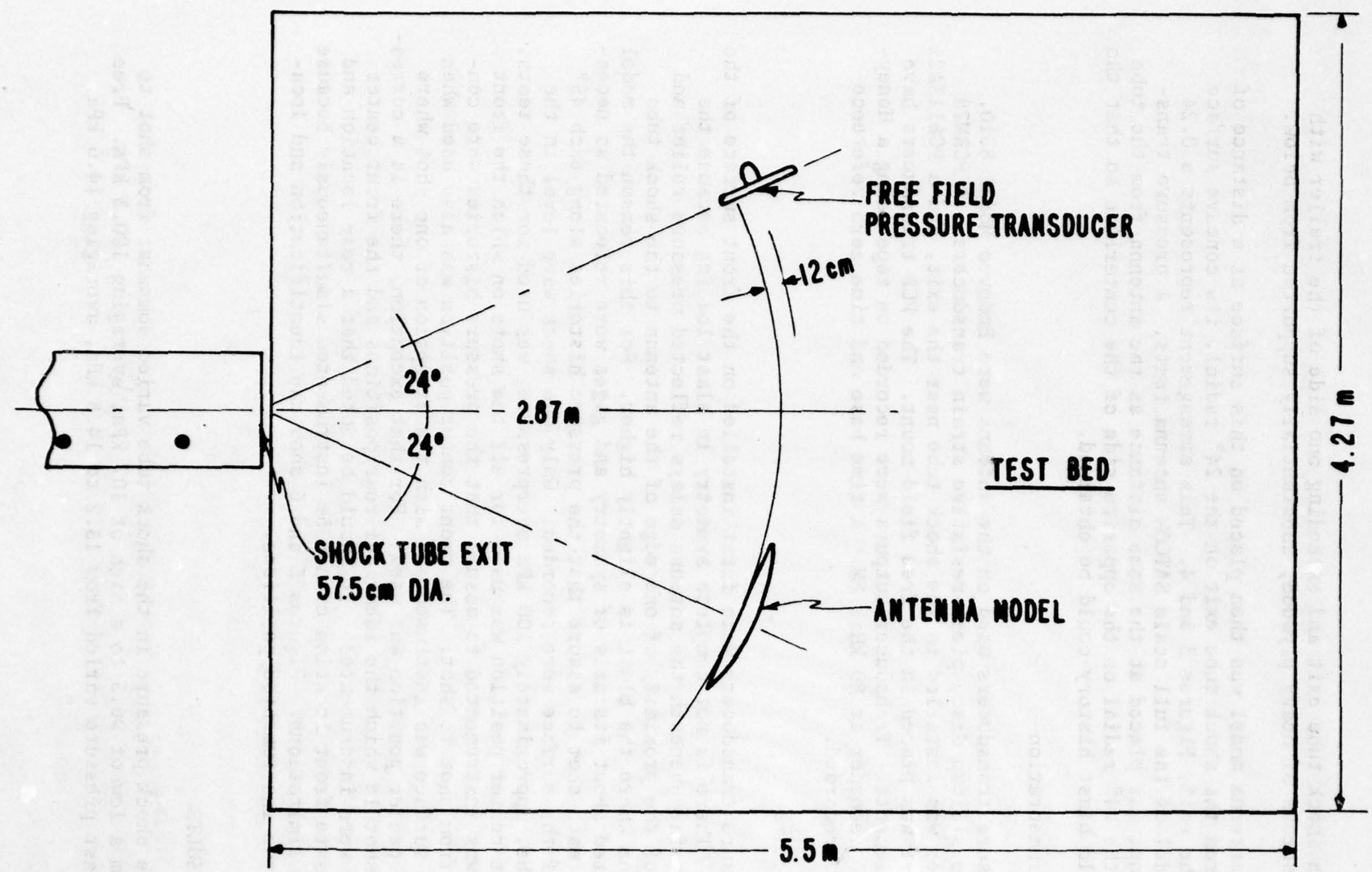
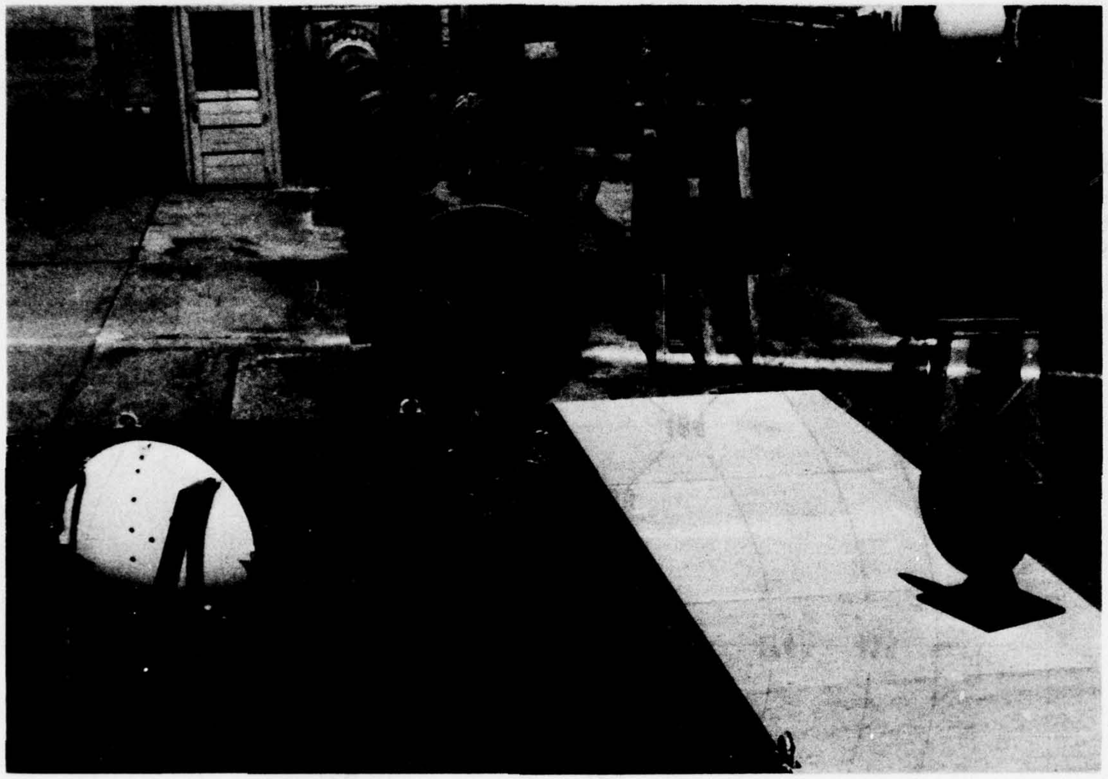
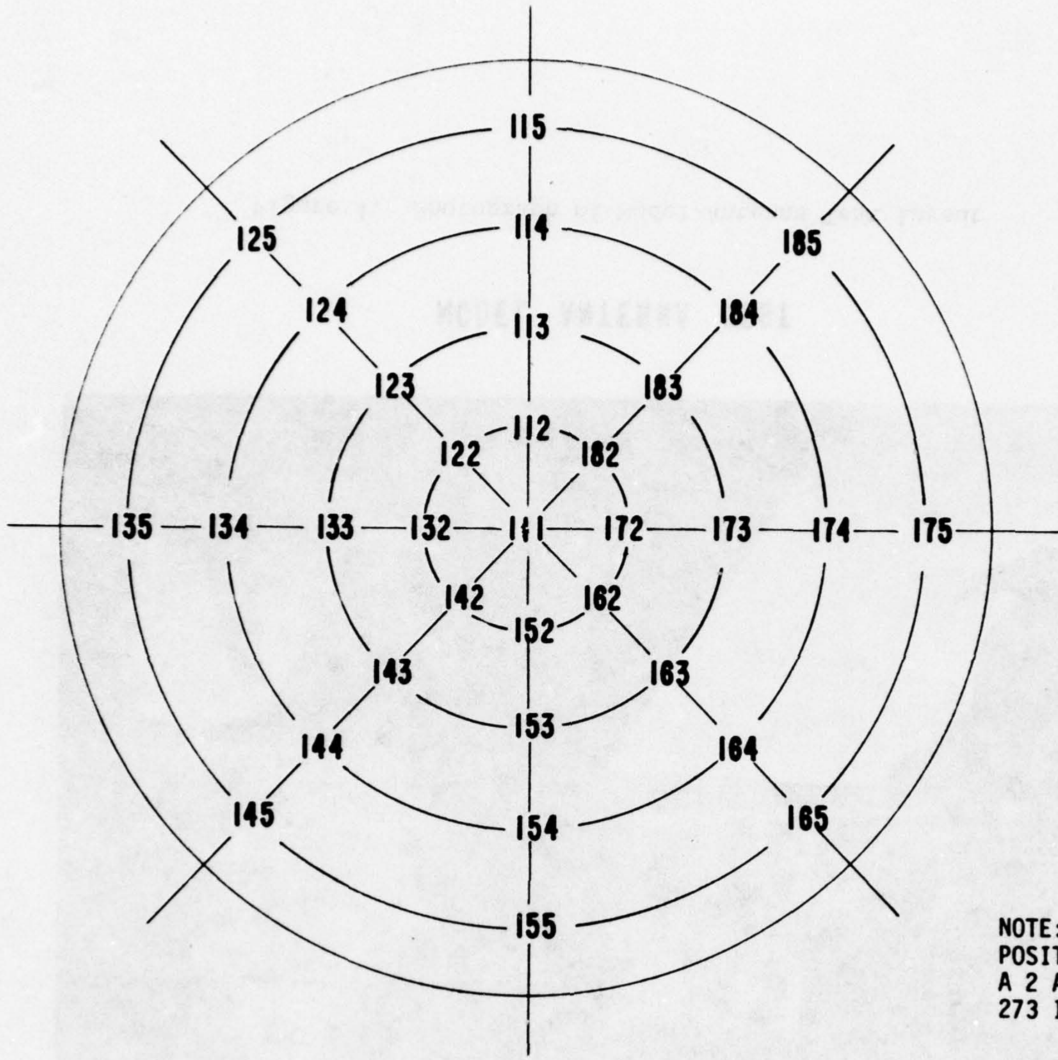


Figure 3. Sketch of Model Antenna Test Layout



MODEL ANTENNA TEST

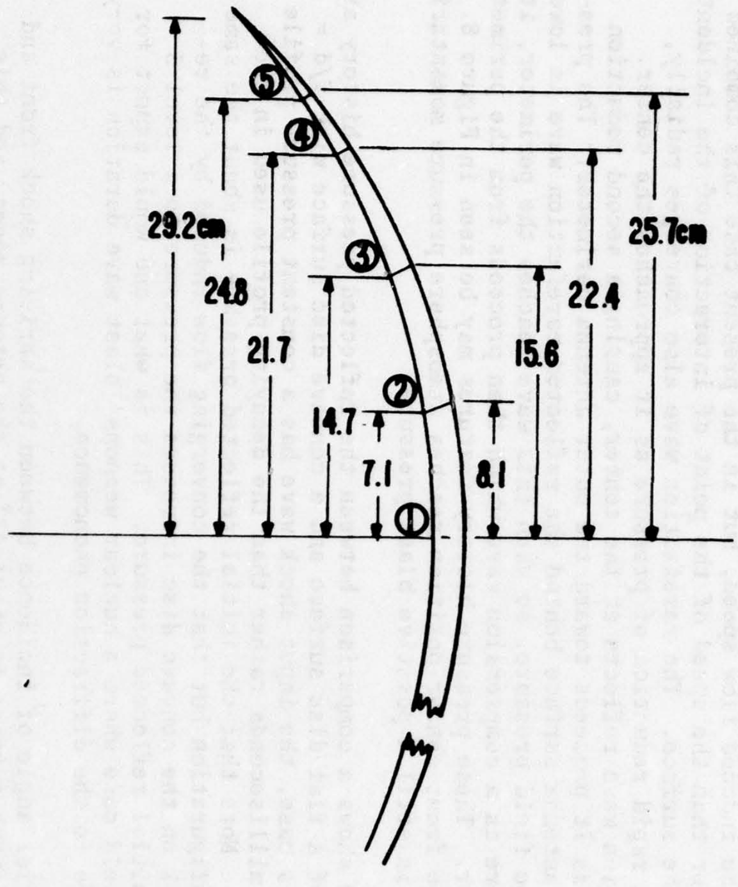
Figure 4. Photograph of Model Antenna Test Layout



NOTE: OPPOSING REAR GAGE POSITIONS ARE NUMBERED WITH A 2 AS THE FIRST DIGIT; I.E.: 273 IS BEHIND 173.

FRONT SURFACE PRESSURE TRANSDUCER POSITIONS

Figure 5. Instrumentation Positions



DISTANCE OF TRANSDUCERS FROM CENTERLINE

Figure 6. Distances of Instrumentation Positions from Centerline

A. Description of Blast/Antenna Interaction

Figure 7 is a sketch of the interaction of the shock front with the antenna. The shock reflects on the concave front surface at an angle, inducing a flow that travels radially inward. This mass flow converging toward the center of the antenna causes a gradual compression following the initial reflection shock pressure. The magnitude of the compression increases at positions closer to the center. Closely following the point of interaction of the shock front with the front surface is a rarefaction wave that is the result of difference in pressure at the front surface and the free edges of the antenna. This wave travels at the local sound speed plus the induced flow speed, but in the present case this combined speed is lower than the speed of the point of interaction of the incident shock with the surface. The rarefaction wave also converges radially, resulting in rapid reduction of pressure as it approaches the center. The rarefaction wave reflects at the center, causing a second reduction in pressure as it proceeds toward the outer antenna perimeter. The pressure on the antenna surface behind the reflected rarefaction wave is lower than the free field pressure, so when this wave reaches the perimeter, it reflects there as a compression wave which then proceeds from the perimeter to the center. These pressure history features may be seen in Figure 8. Note that the front center position reaches atmosphere pressure momentarily while there is still a positive blast pressure.

Figure 9 shows a comparison between the reflected pressure history at the center of a flat disc surface and a concave disc surface with f/d = 0.3. In this case, the input shock wave has a constant pressure profile for several milliseconds rather than the decaying profile used in the model tests. Note that the initial reflected pressure is about the same for each configuration but that the converging flow induced by the reflected shock on the concave disc increases the pressure to a level 3 times the initial reflected pressure. This is what one would expect for the battlefield case where a nuclear weapons' blast wave duration is very long compared to the diffraction phenomenon.

The initial angle of incidence between the arriving shock front and the antenna front surface is about 42° at the antenna edges, and this angle decreases to 0° at the antenna center. Regular reflection theory, verified by experiment, shows that, at this shock pressure, P_s, and for angles of incidence in this range, the reflected pressure factor P_R/P_S is practically constant at 2.11. We may then expect that the initial reflected pressure will be the same at this shock pressure for the entire front surface. The induced radial flow velocity is of course greater at the greater angles of incidence occurring nearer the antenna edge but that does not affect the initial reflected pressure.

As the shock refracts around the antenna edges and expands inward towards the rear center, it is initially weakened. This weakened initial shock is followed by an increase in pressure as the flow induced by this

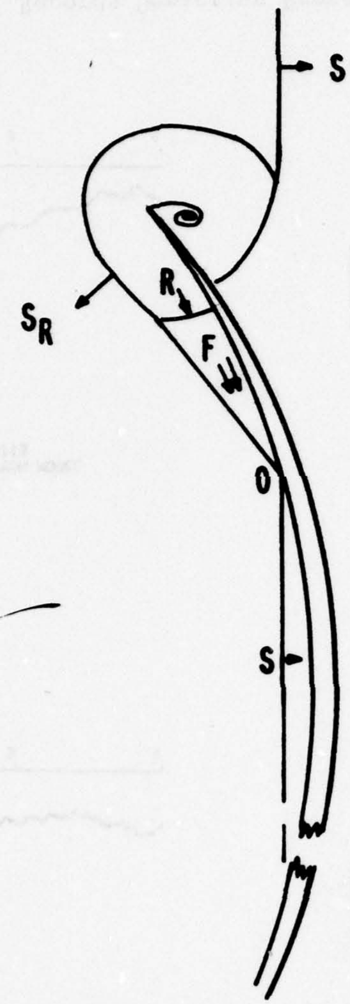


Figure 7. Shock Interaction with Antenna

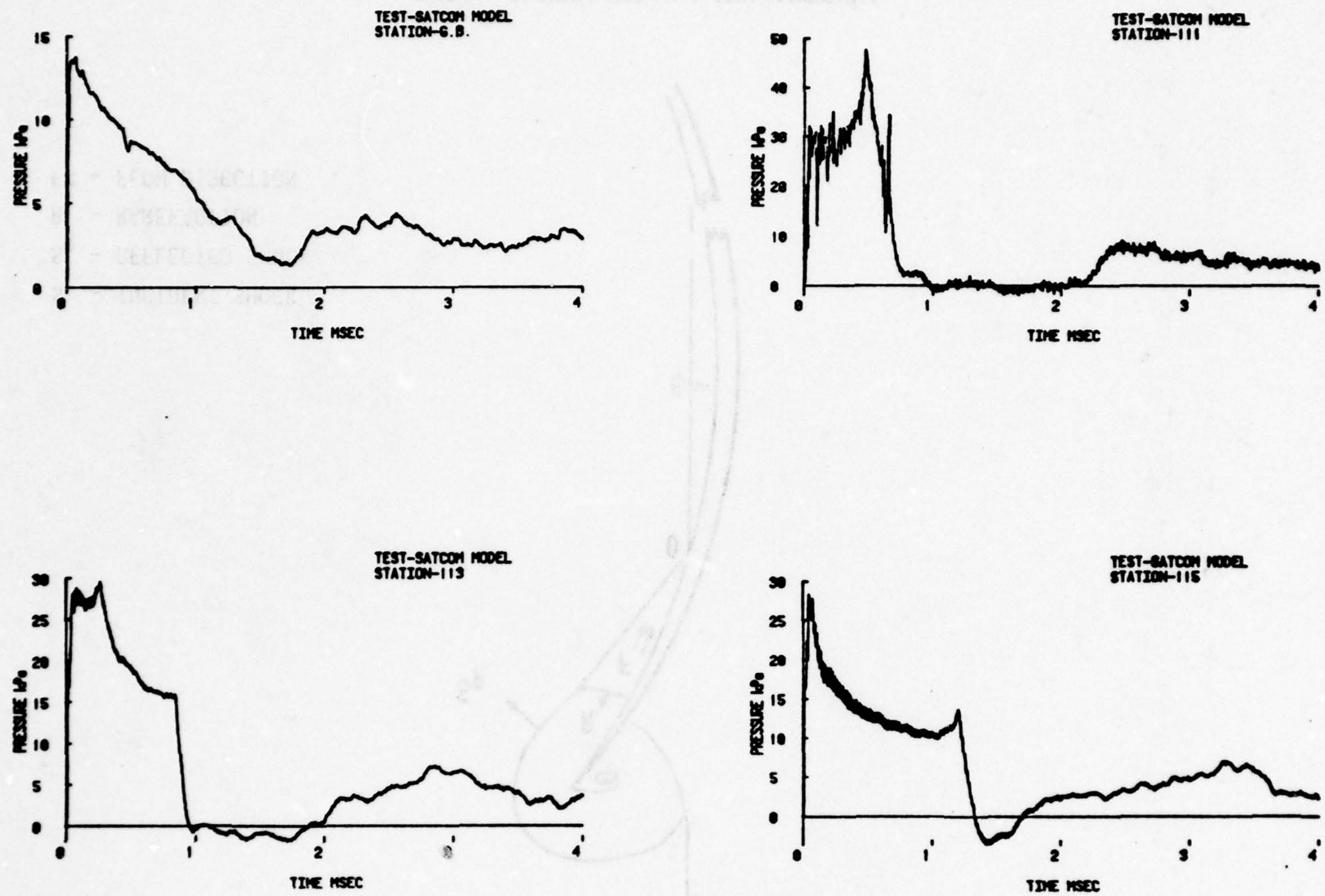


Figure 8. Records Depicting Pressure History Features

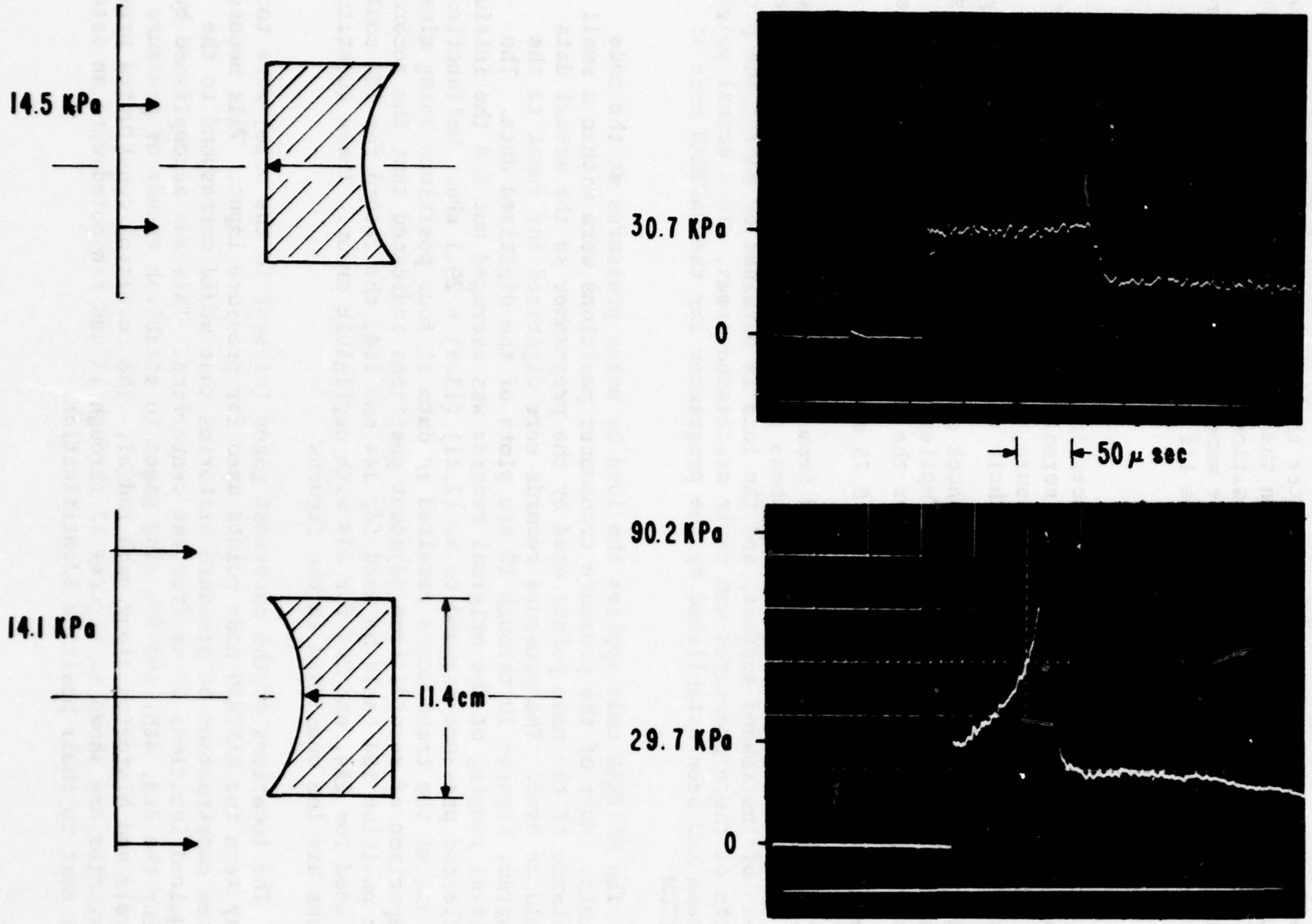


Figure 9. Comparison of Pressure History on Flat and Concave Discs

shock also converges toward the center from the antenna perimeter. The shock arrives at rear positions later than it does at corresponding front positions since it must travel down the back surface. It is interesting to observe that the rear center position pressure reaches a maximum at the same time the front center pressure momentarily reaches ambient pressure, as shown in the record of positions 111 and 211 in Figure 10.

B. Data Reduction

Since there were some differences in free field pressure from shot to shot, the recorded data had to be normalized. The full scale test was at 13.8 kPa free field shock overpressure, so all the data in the present tests were scaled by multiplying their values of pressure P_R by $13.8/P_{FF}$, where P_{FF} is measured free field shock overpressure and P_R is the pressure measured at each position. This implies that the reflected pressure factor P_R/P_{FF} is constant, and over the small range of pressures in the present tests this is true within 0.75 sec.

Loading histories are obtained from the pressure histories. A scheme is normally devised to associate these pressure histories with specific areas of the loaded surface, and the load is obtained by adding the products of these pressures and their associated areas. This actual weighting scheme had been established by the programmer for the NASTRAN code at SATCOM.

The NASTRAN code applies the load by using pressures at the node points. Most of the pressure transducer positions were within a small distance of the node points used by the programmer so the actual data could be used. The pressure records were digitized for input to the program; Figures 10 through 12 are plots of the digitized data. The initial ringing of the original records was averaged out and the initial reflected pressure assumed to be (2.11) (13.8) = 29.1 kPa. Malfunction of one of the transducers resulted in data at four positions being missed. Comparison of records from adjacent positions indicated that the record for position 154 could be used for 144 and 164, the record for 124 could be used for 184, and 264 for 244 with negligible error. These substitutions are the ones used in the figures.

The locations of the outermost gages (closest to the edge) were too far away from the NASTRAN node points used for pressure input. This necessitated construction of pressure histories that would correspond to the required locations 28 cm from the centerline. This was accomplished by using the 3rd, 4th, and 5th ring gages to establish trends of pressure levels and histories along each radial. The resulting constructed pressure histories are shown in Figures 13 through 14 and are noted with an asterisk (*) next to their position identification.

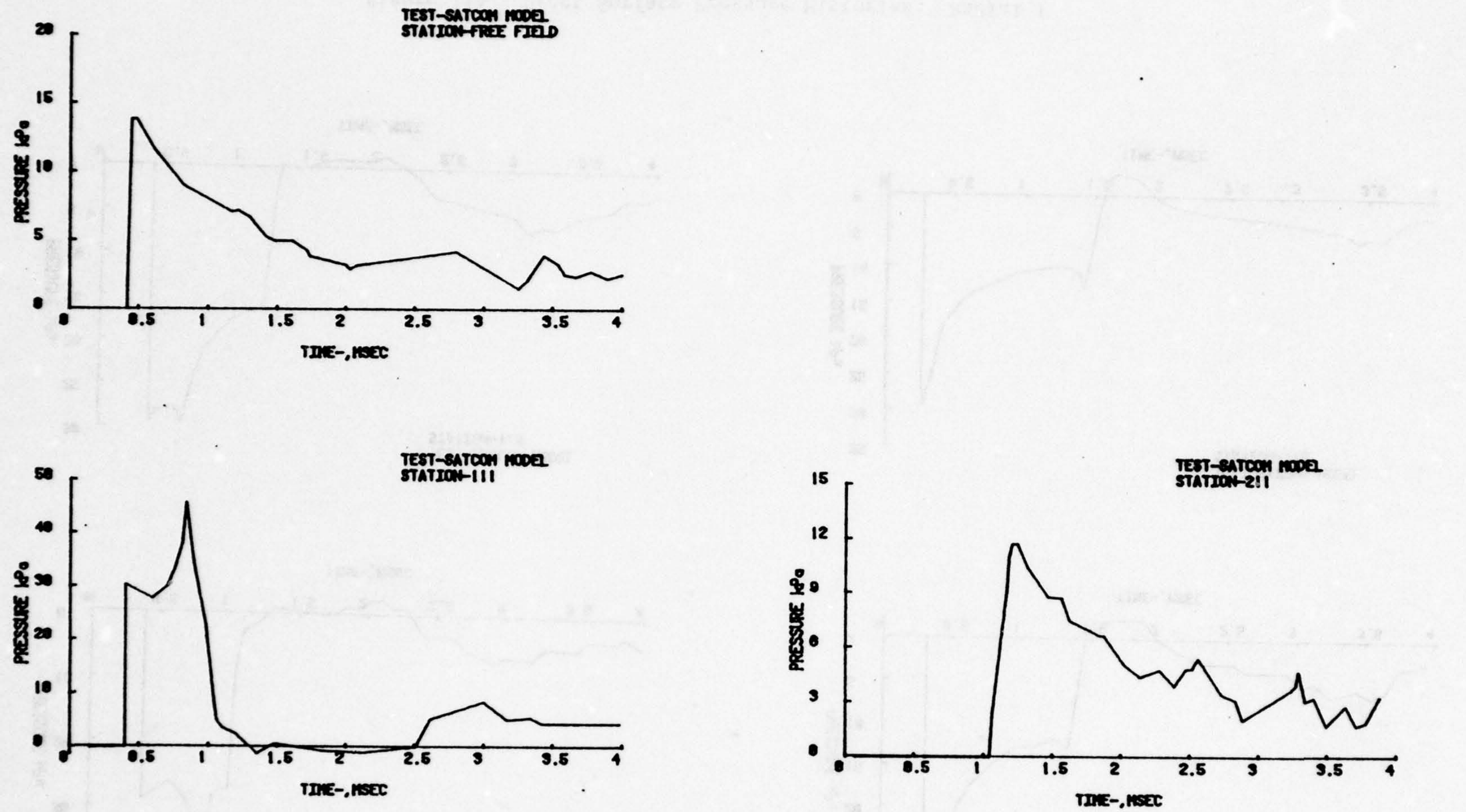


Figure 10. Pressure History at Front and Rear Center

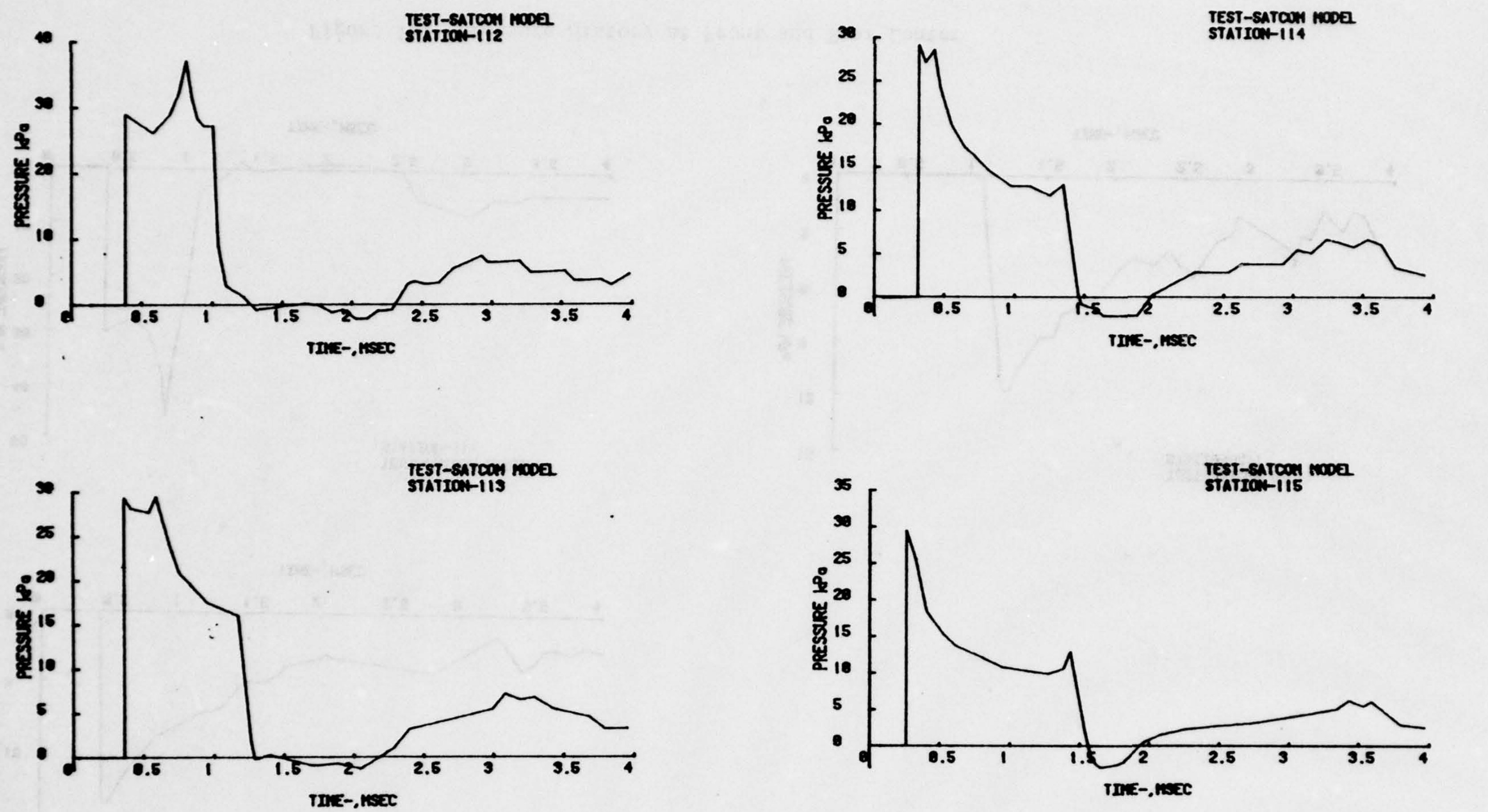


Figure 11a. Front Surface Pressure Histories: Radial 1

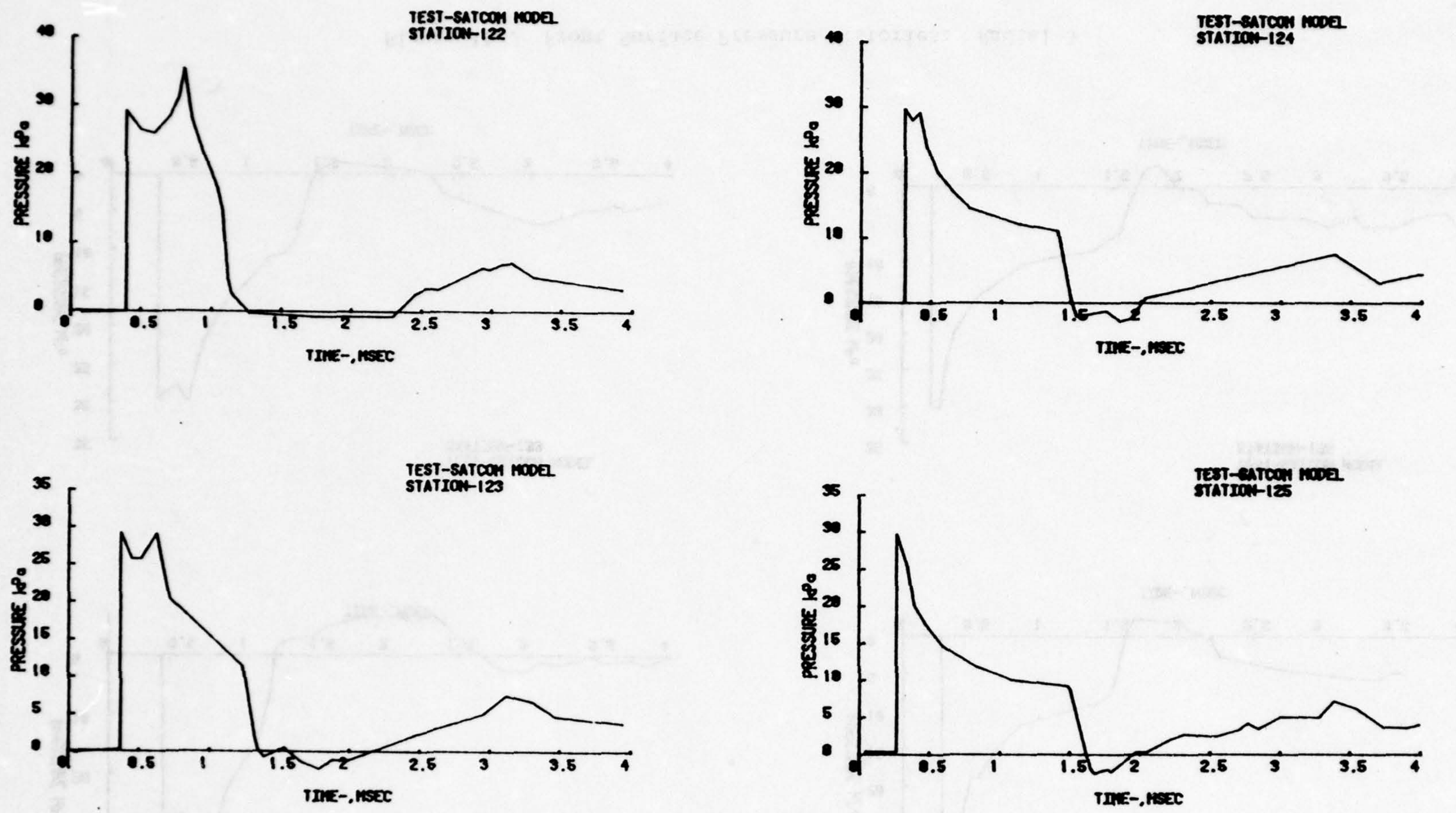


Figure 11b. Front Surface Pressure Histories: Radial 2

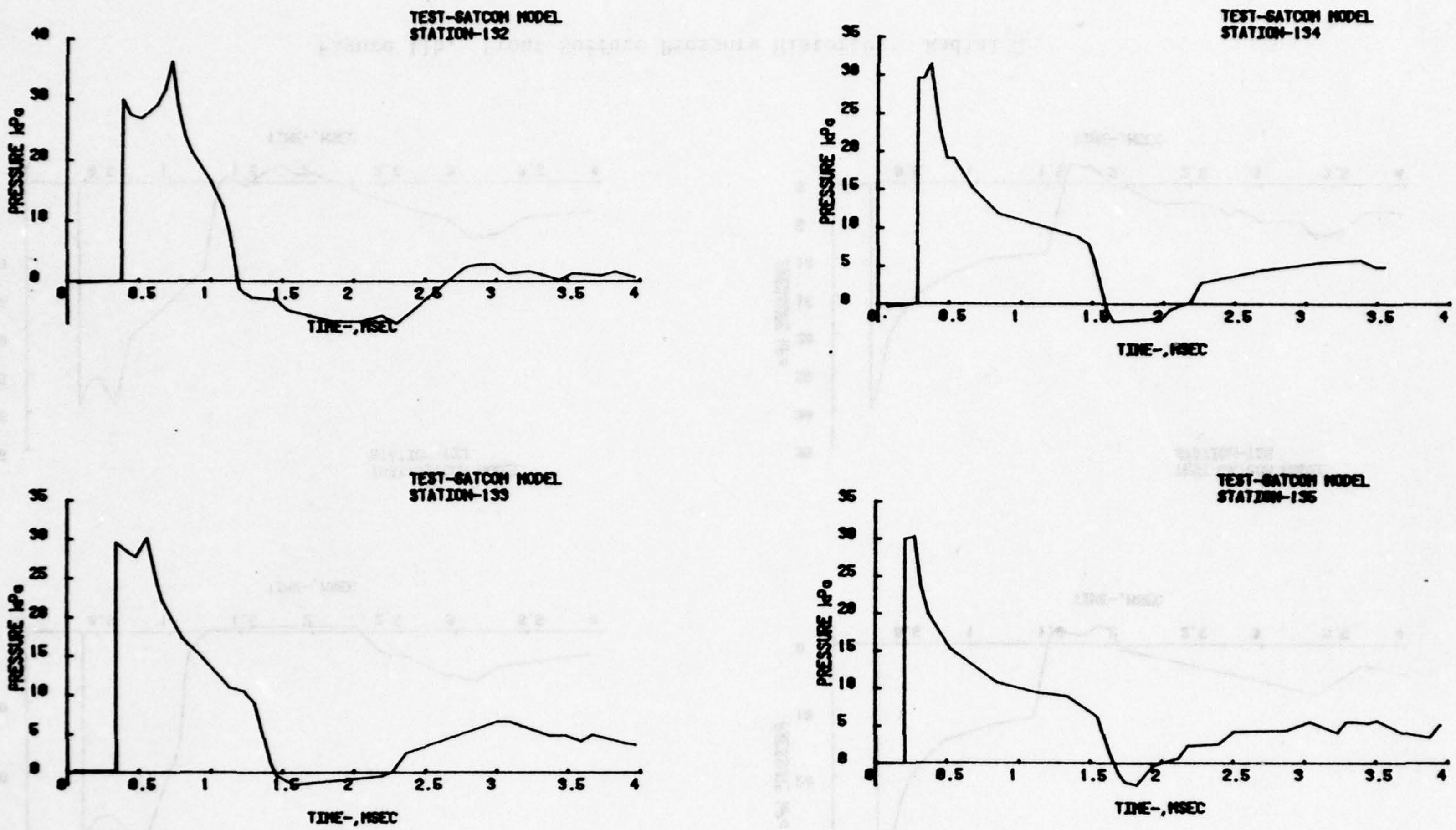


Figure 11c. Front Surface Pressure Histories: Radial 3

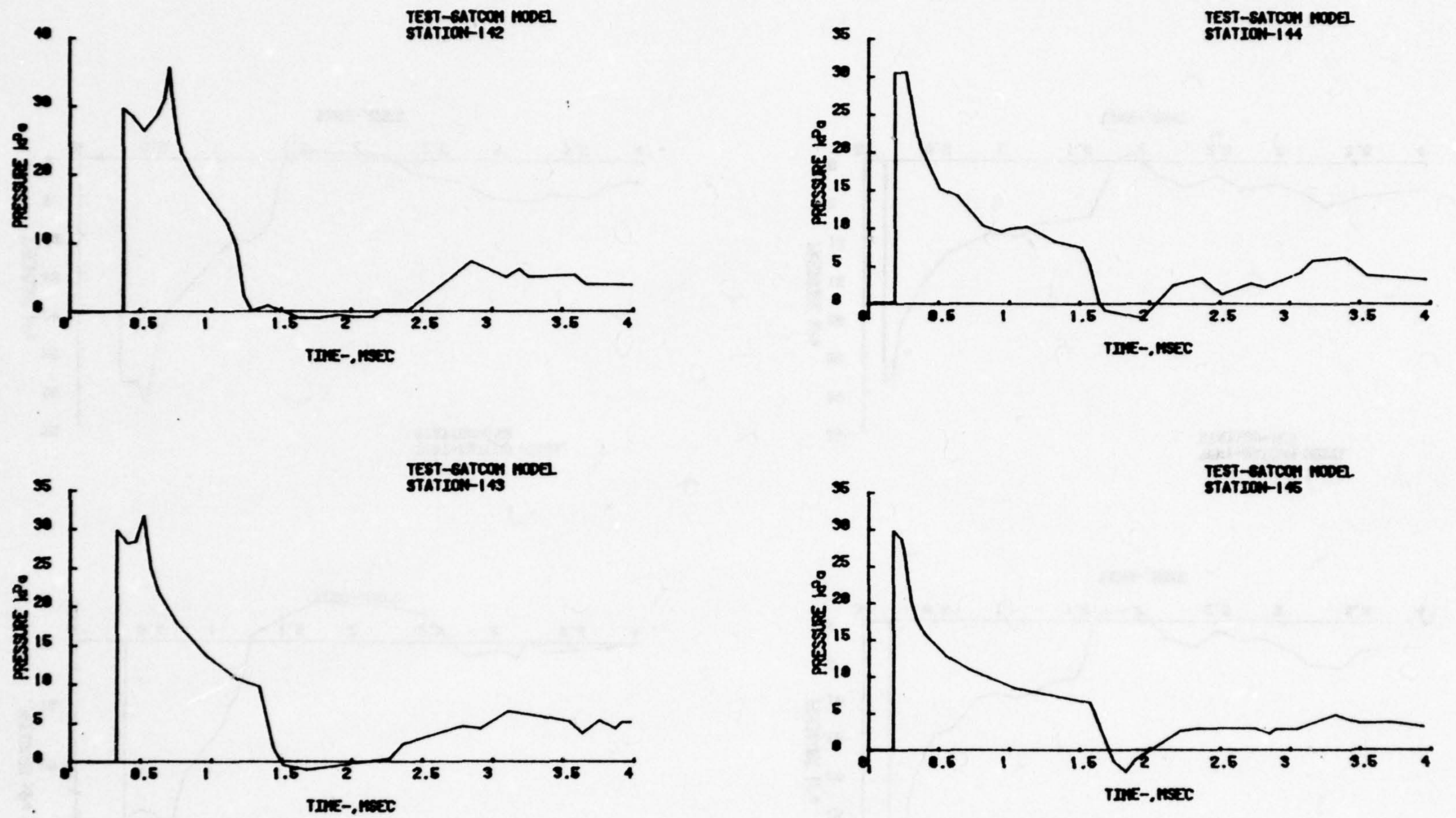


Figure 11d. Front Surface Pressure Histories: Radial 4

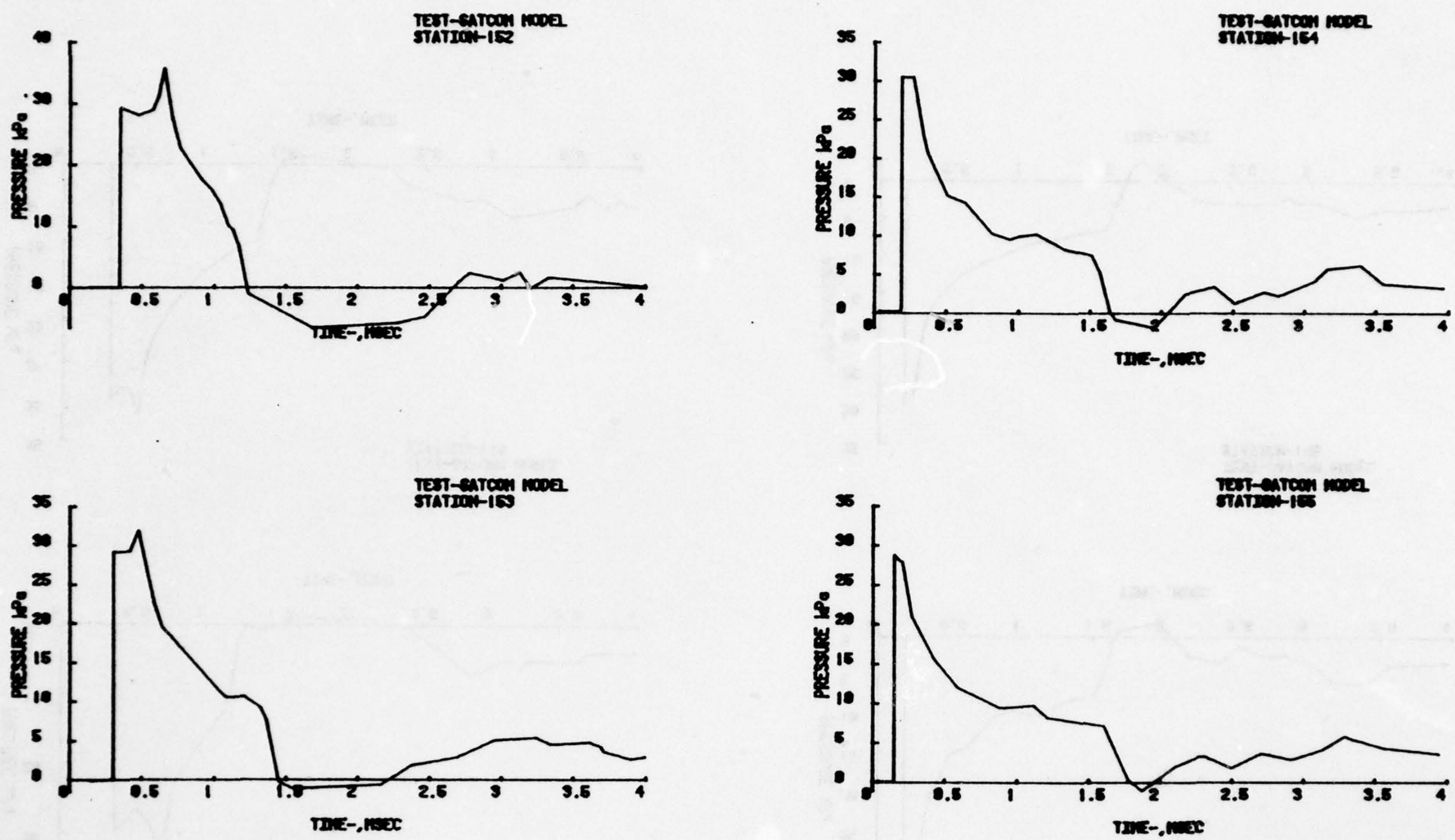


Figure 11e. Front Surface Pressure Histories: Radial 5

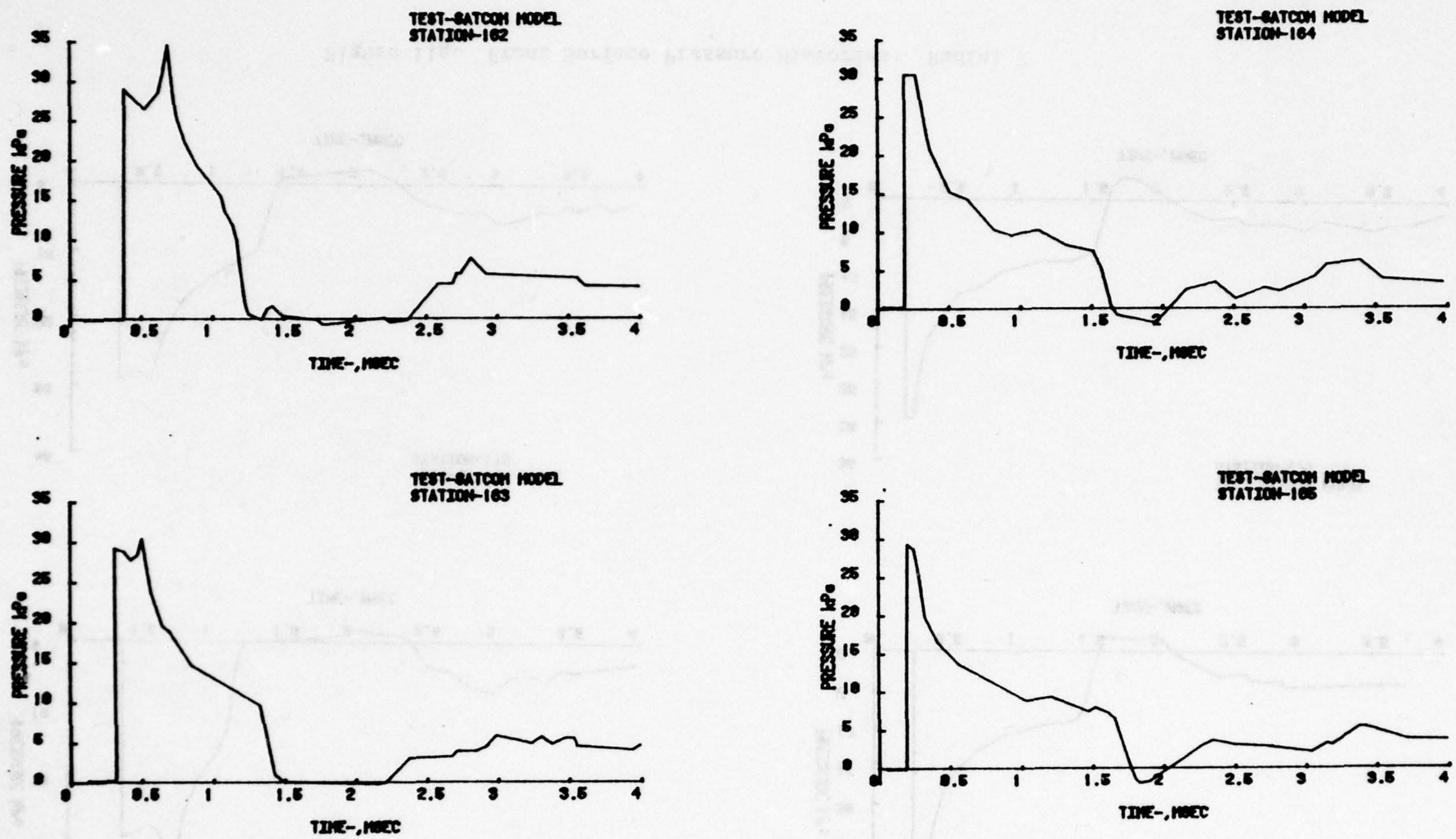


Figure 11f. Front Surface Pressure Histories: Radial 6

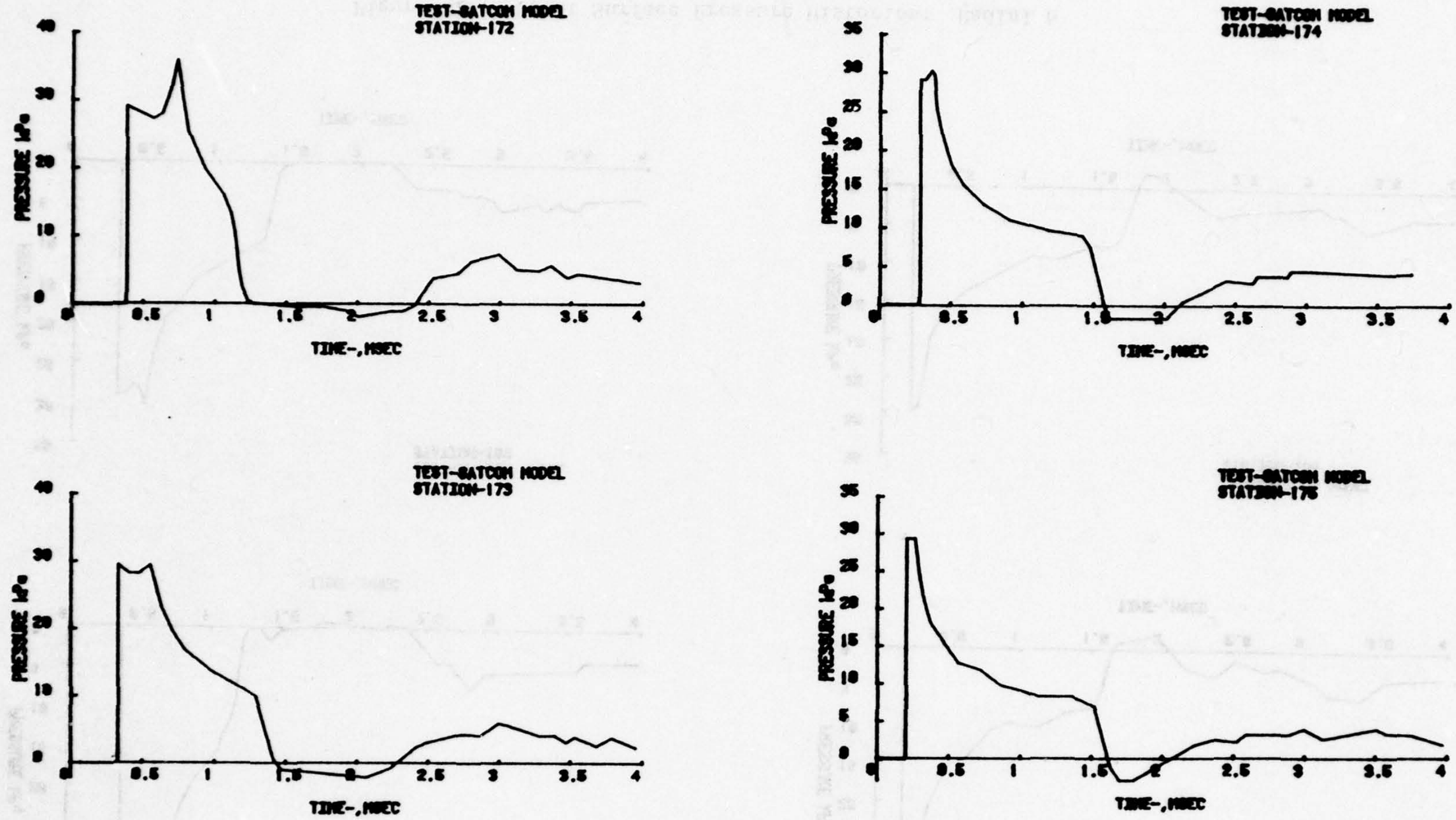


Figure 11g. Front Surface Pressure Histories: Radial 7

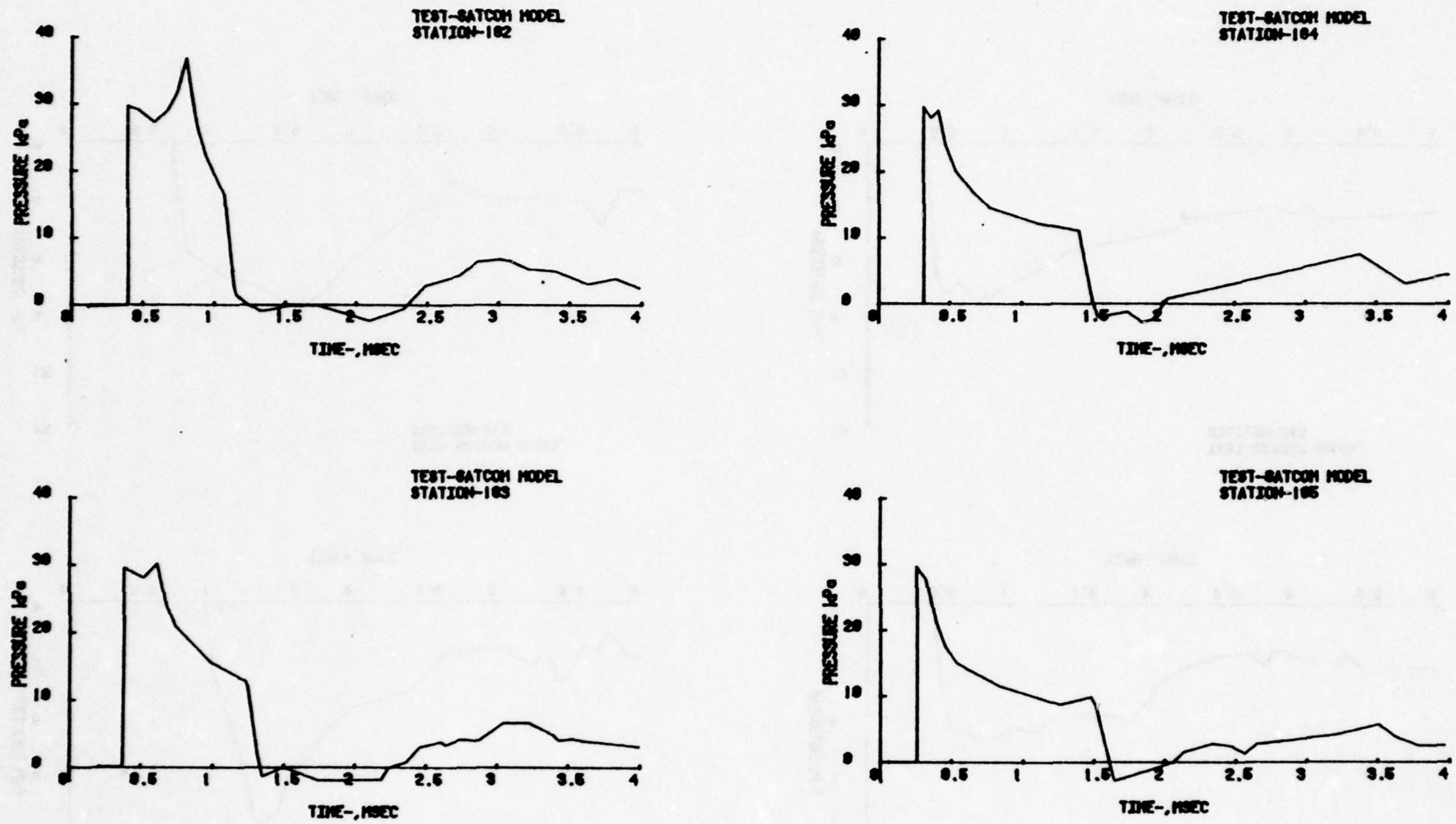


Figure 11h. Front Surface Pressure Histories: Radial 8

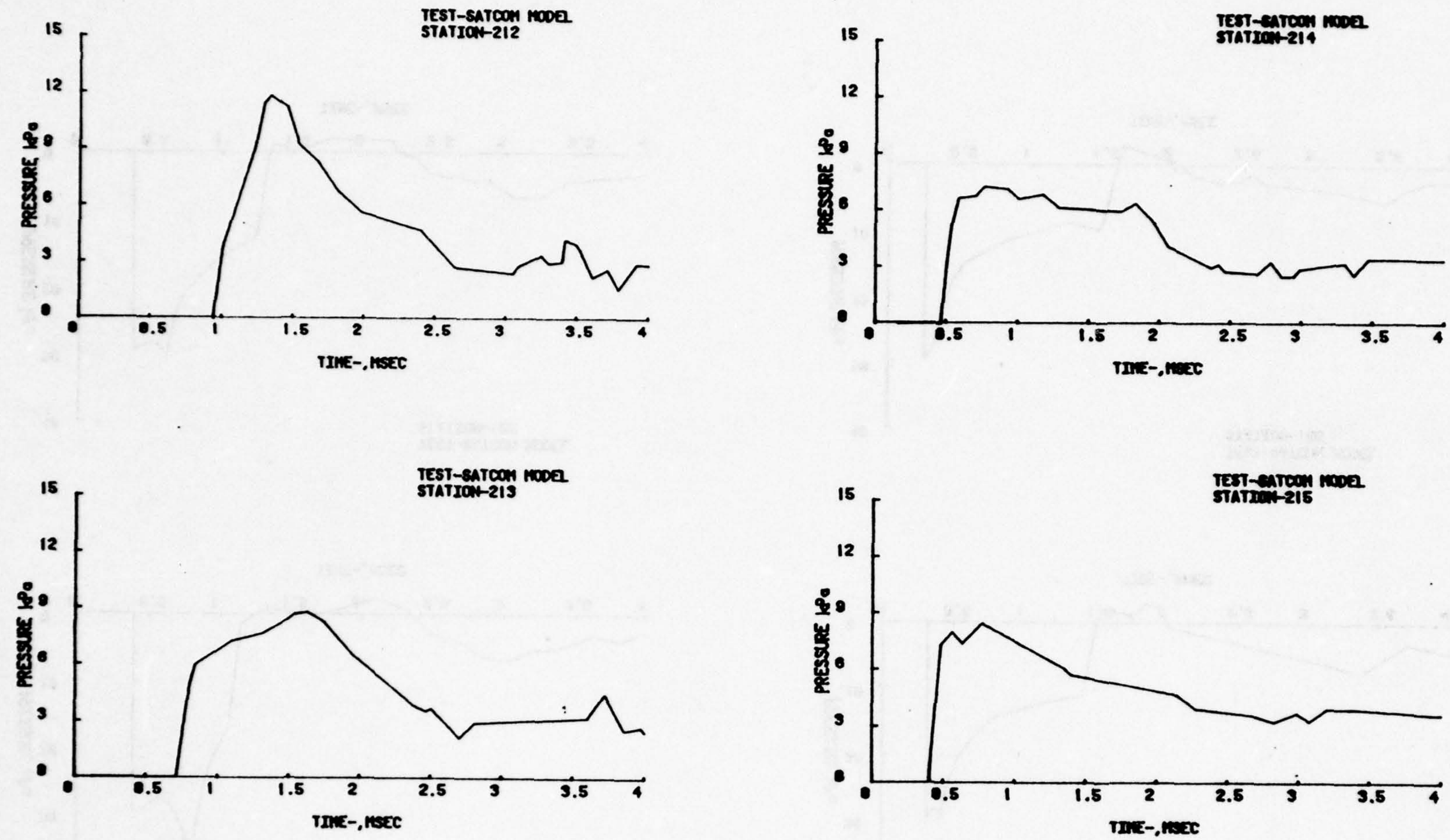


Figure 12a. Rear Surface Pressure Histories: Radial 1

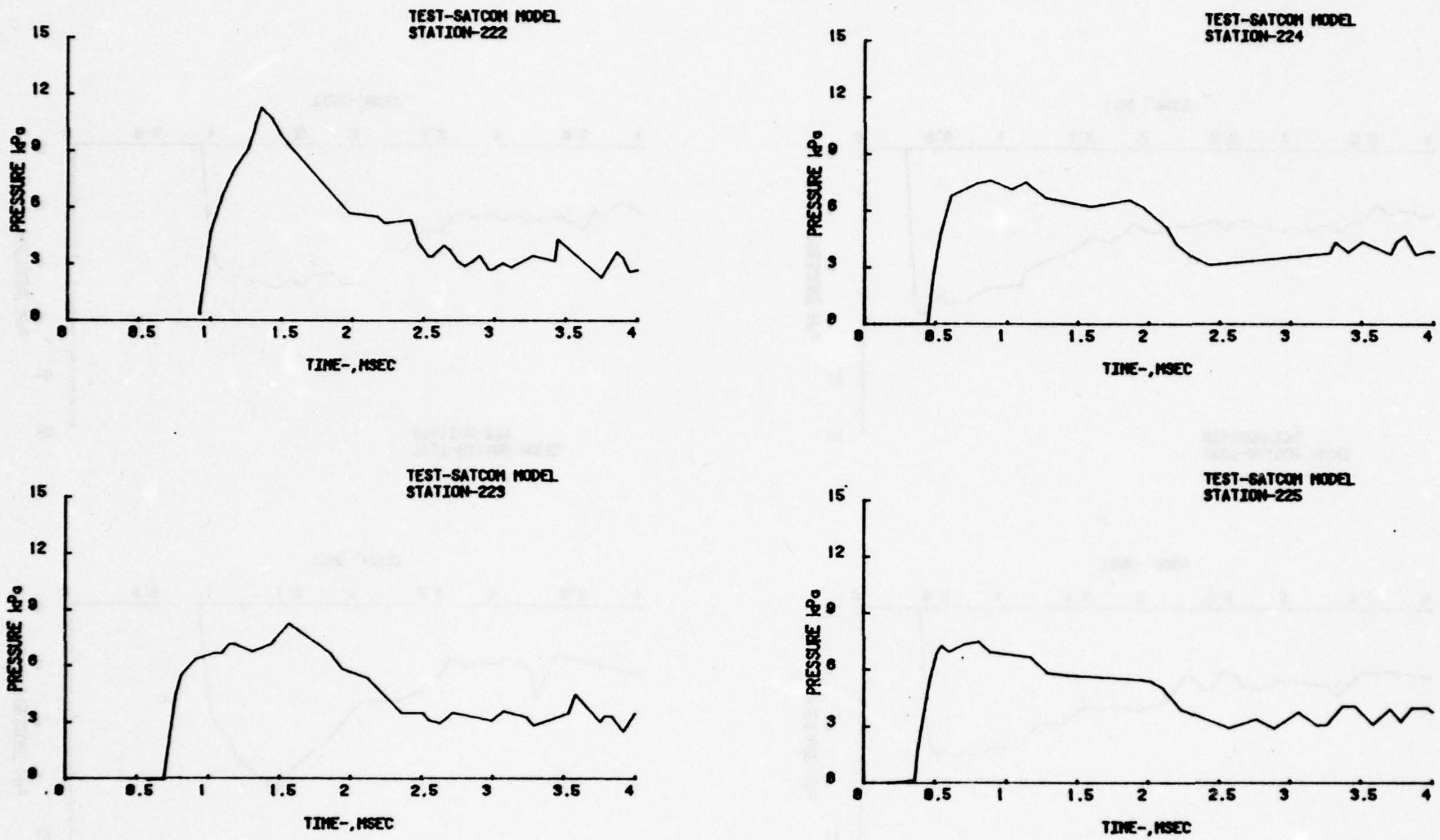


Figure 12b. Rear Surface Pressure Histories: Radial 2

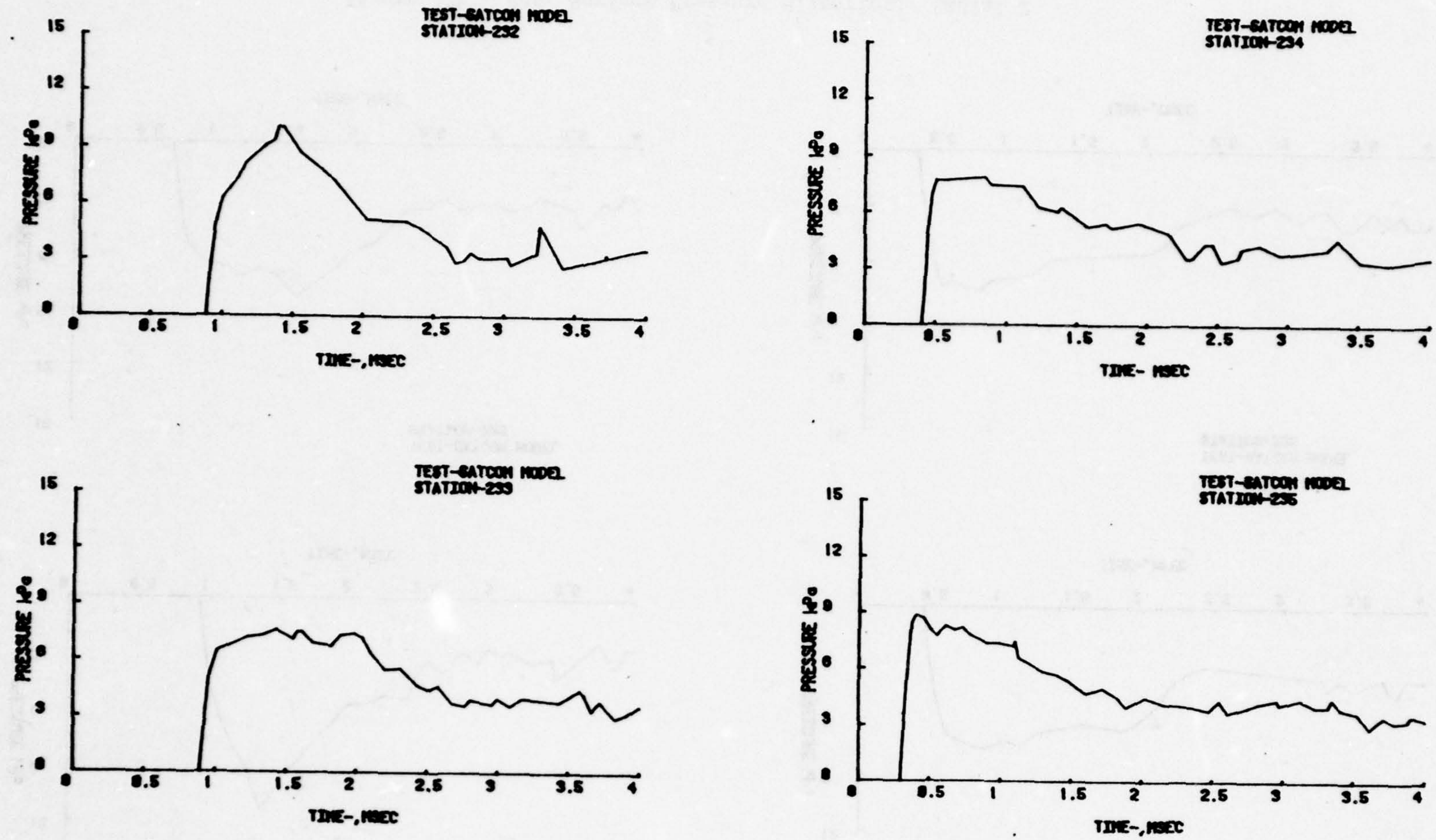


Figure 12c. Rear Surface Pressure Histories: Radial 3

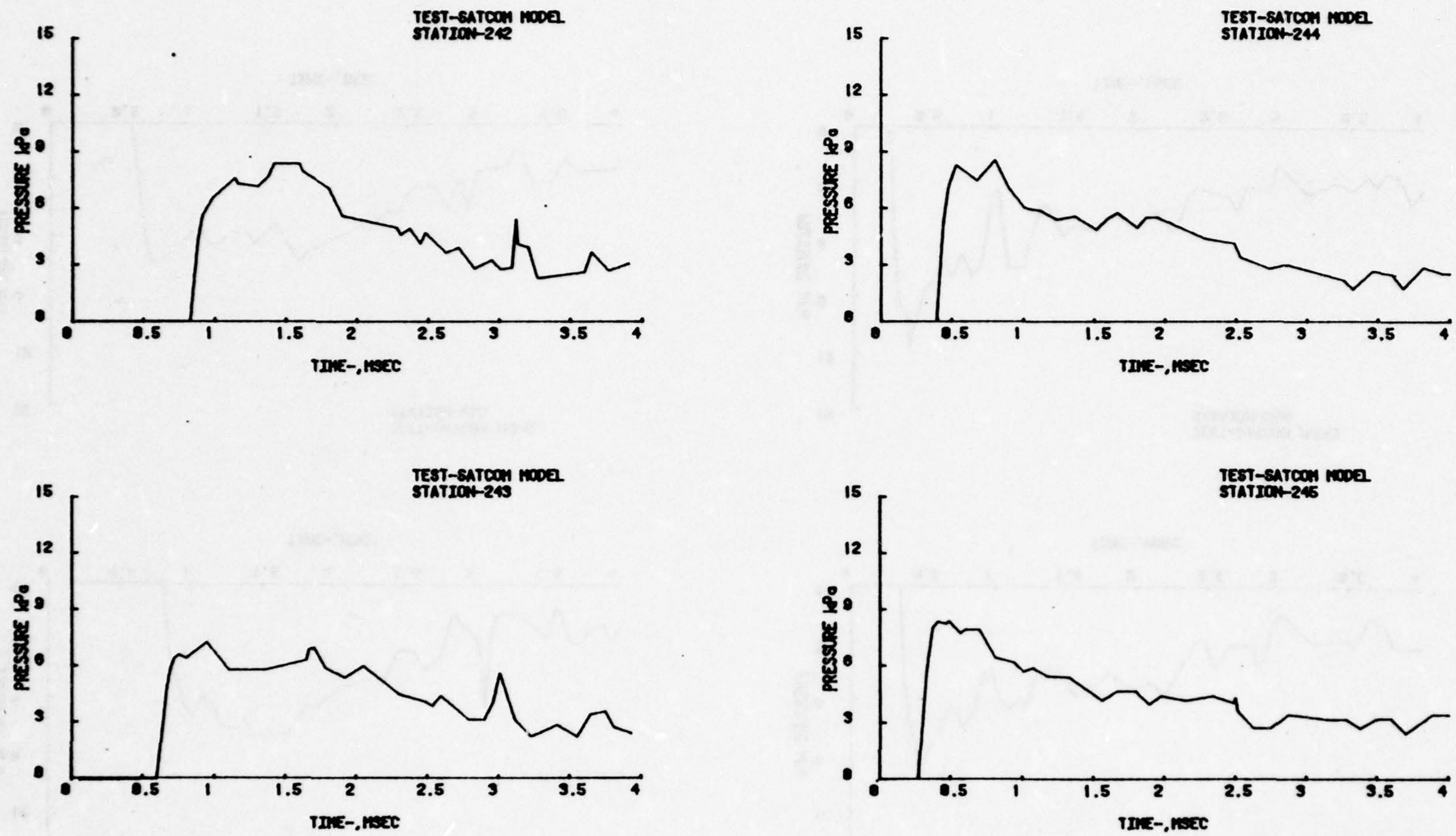


Figure 12d. Rear Surface Pressure Histories: Radial 4

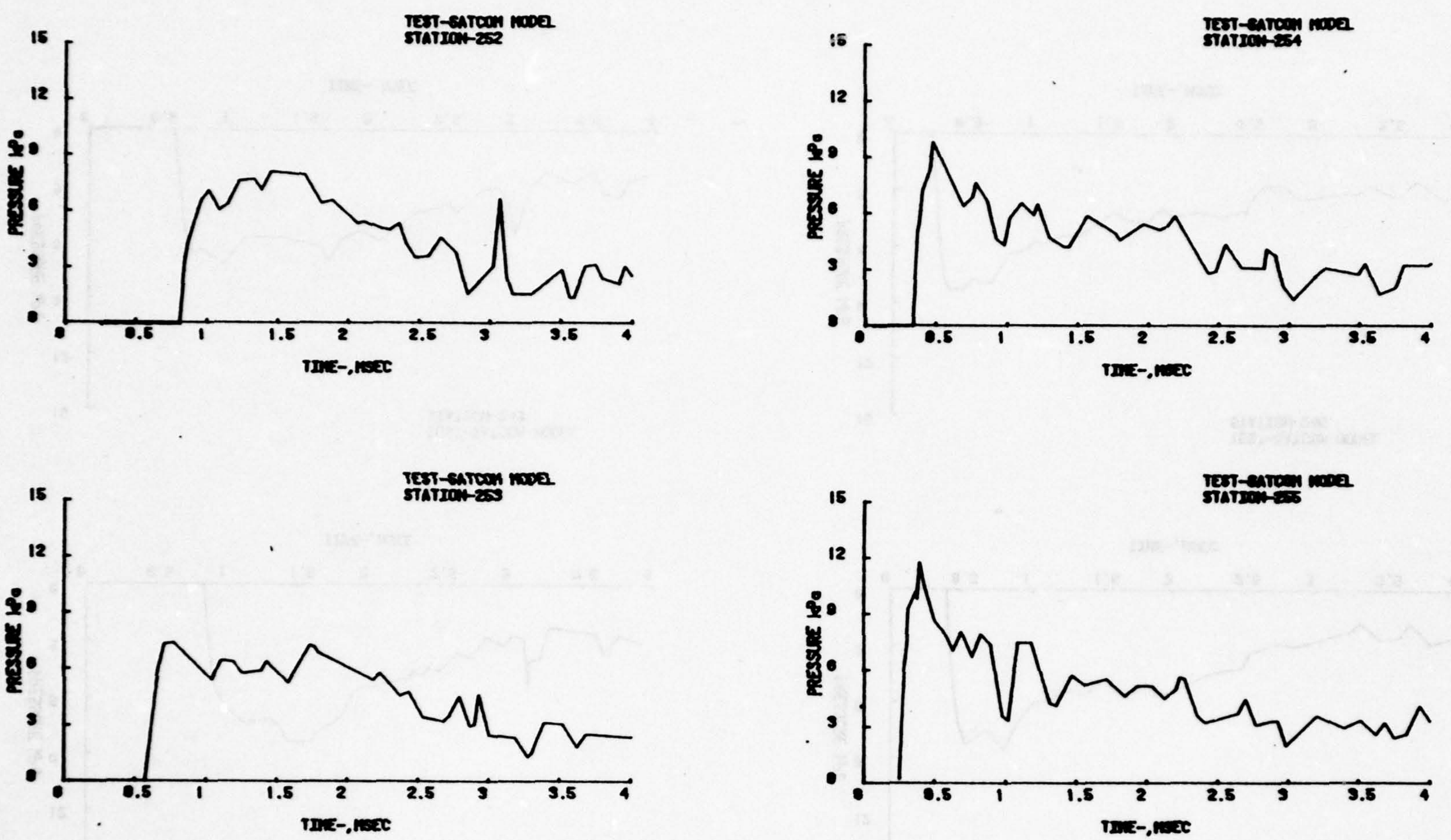
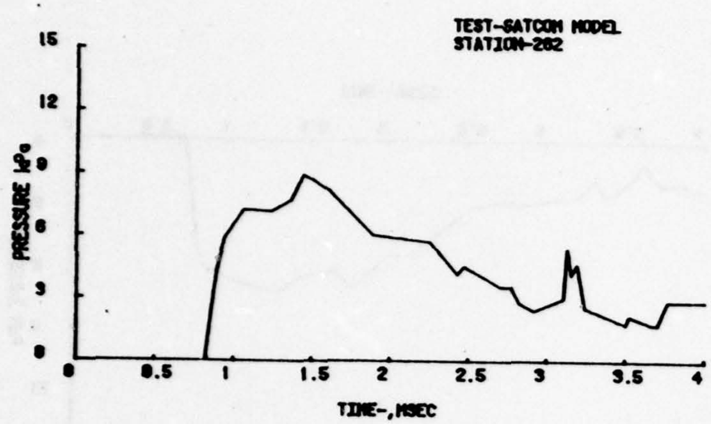
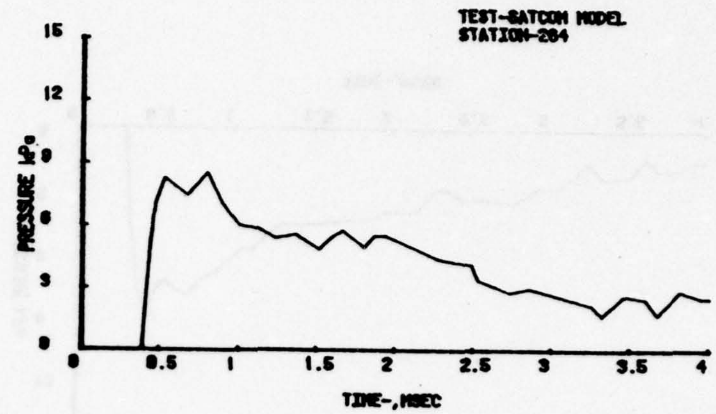
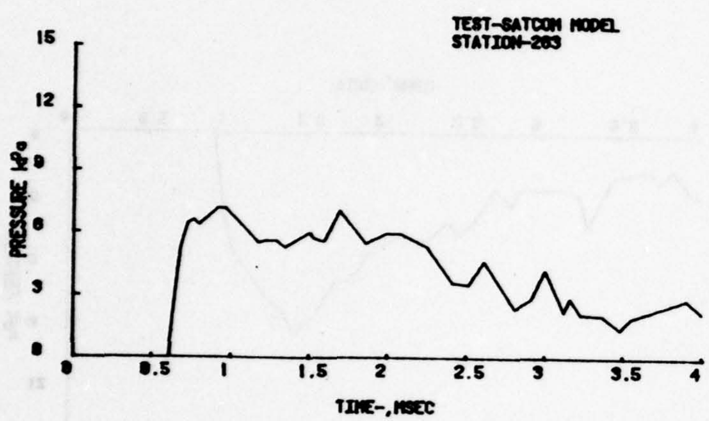


Figure 12e. Rear Surface Pressure Histories: Radial 5







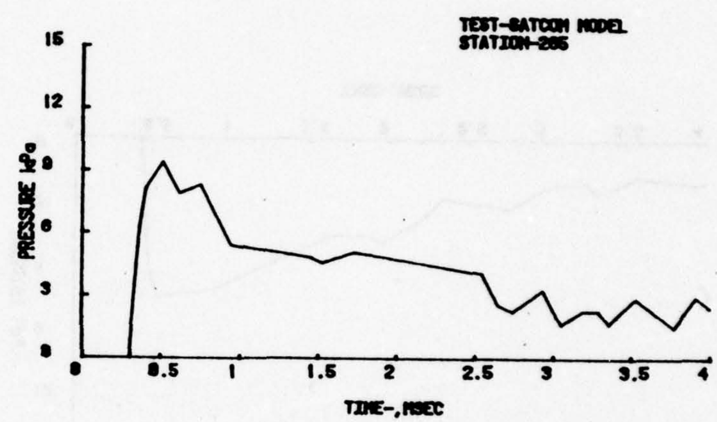


Figure 12f. Rear Surface Pressure Histories: Radial 6

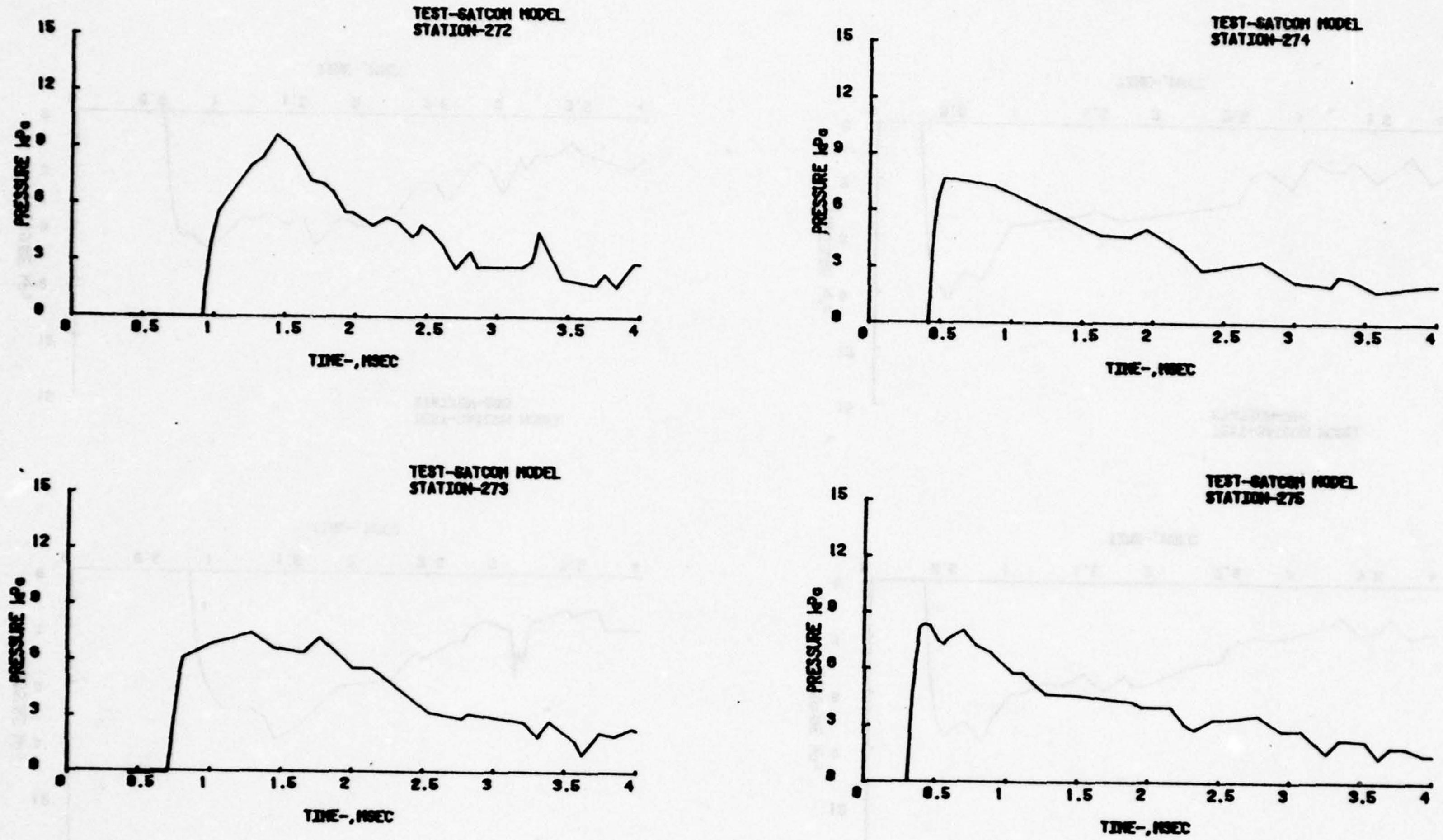


Figure 12g. Rear Surface Pressure Histories: Radial 7

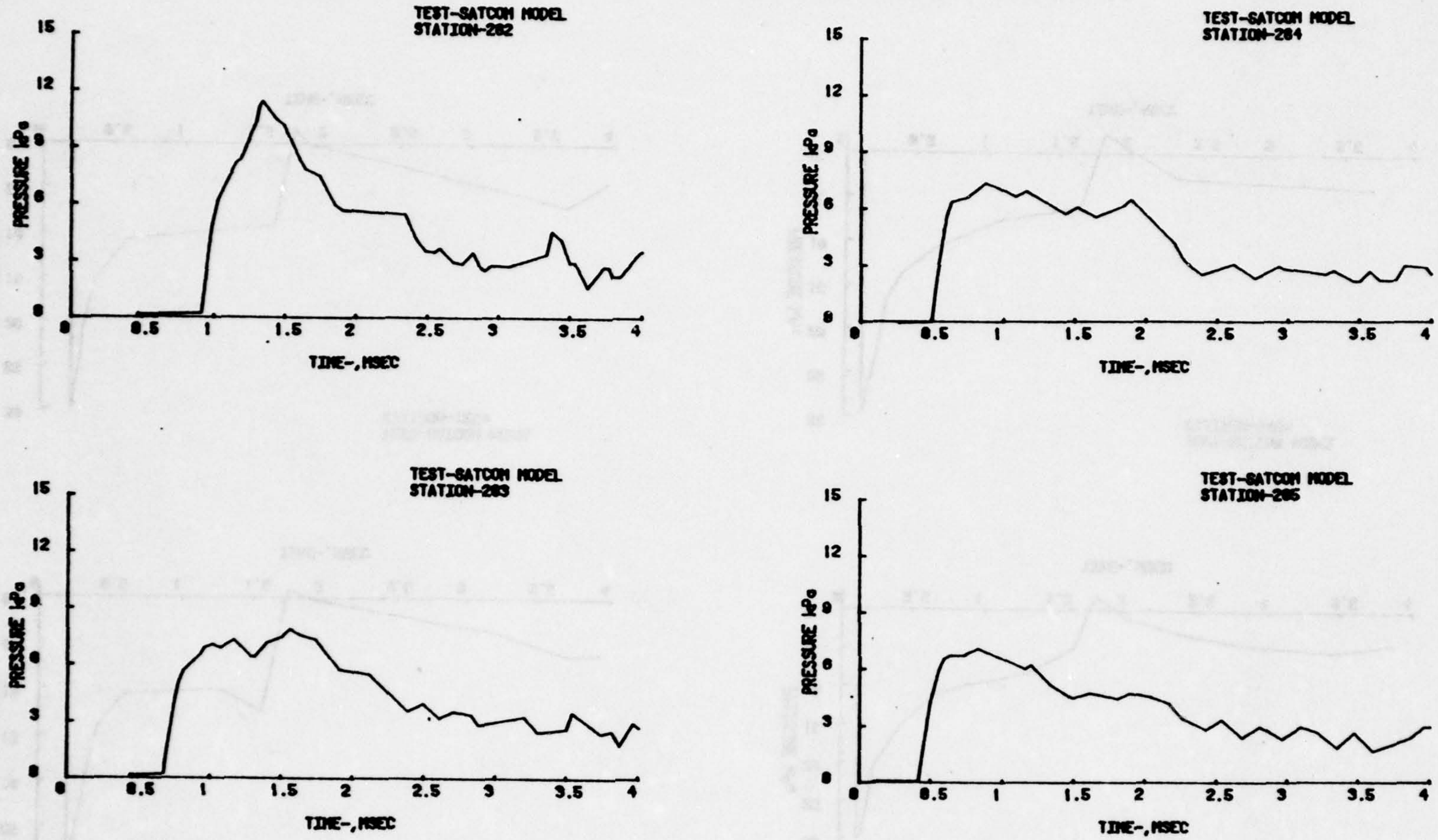


Figure 12h. Rear Surface Pressure Histories: Radial 8

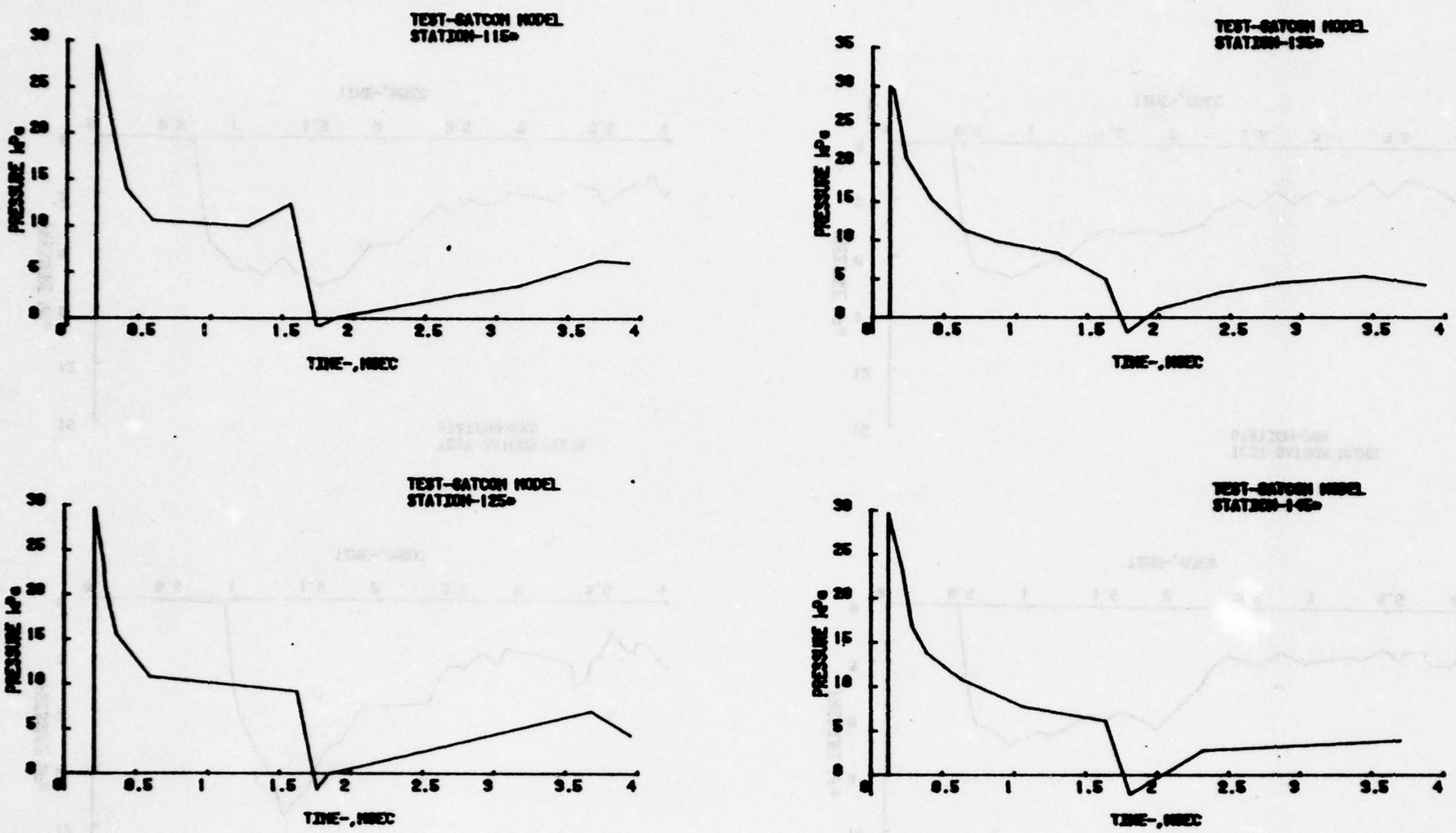


Figure 13. Constructed Pressure Histories, Front Surface Position 5*

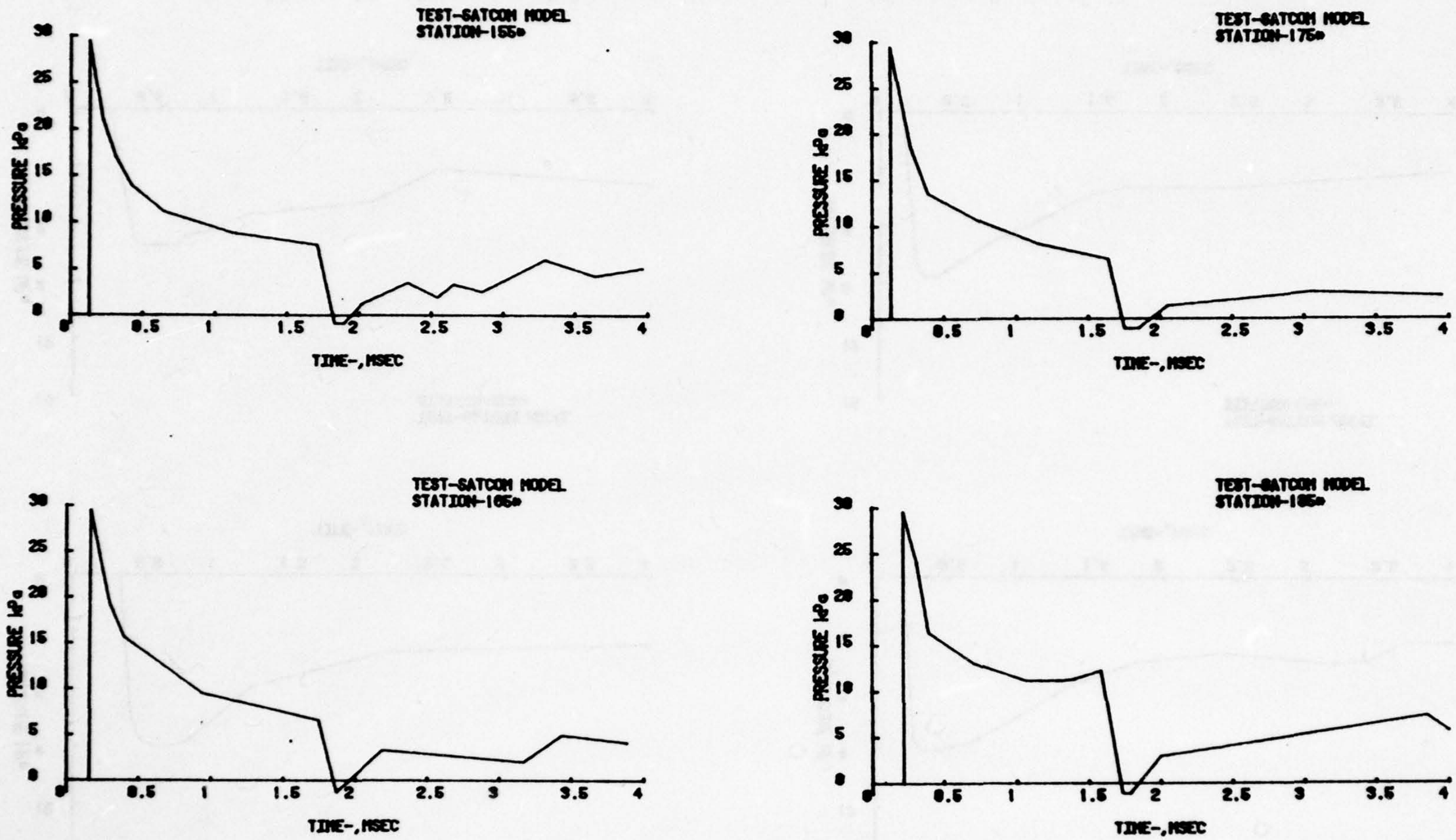


Figure 13 (Continued). Constructed Pressure Histories, Front Surface Position 5*

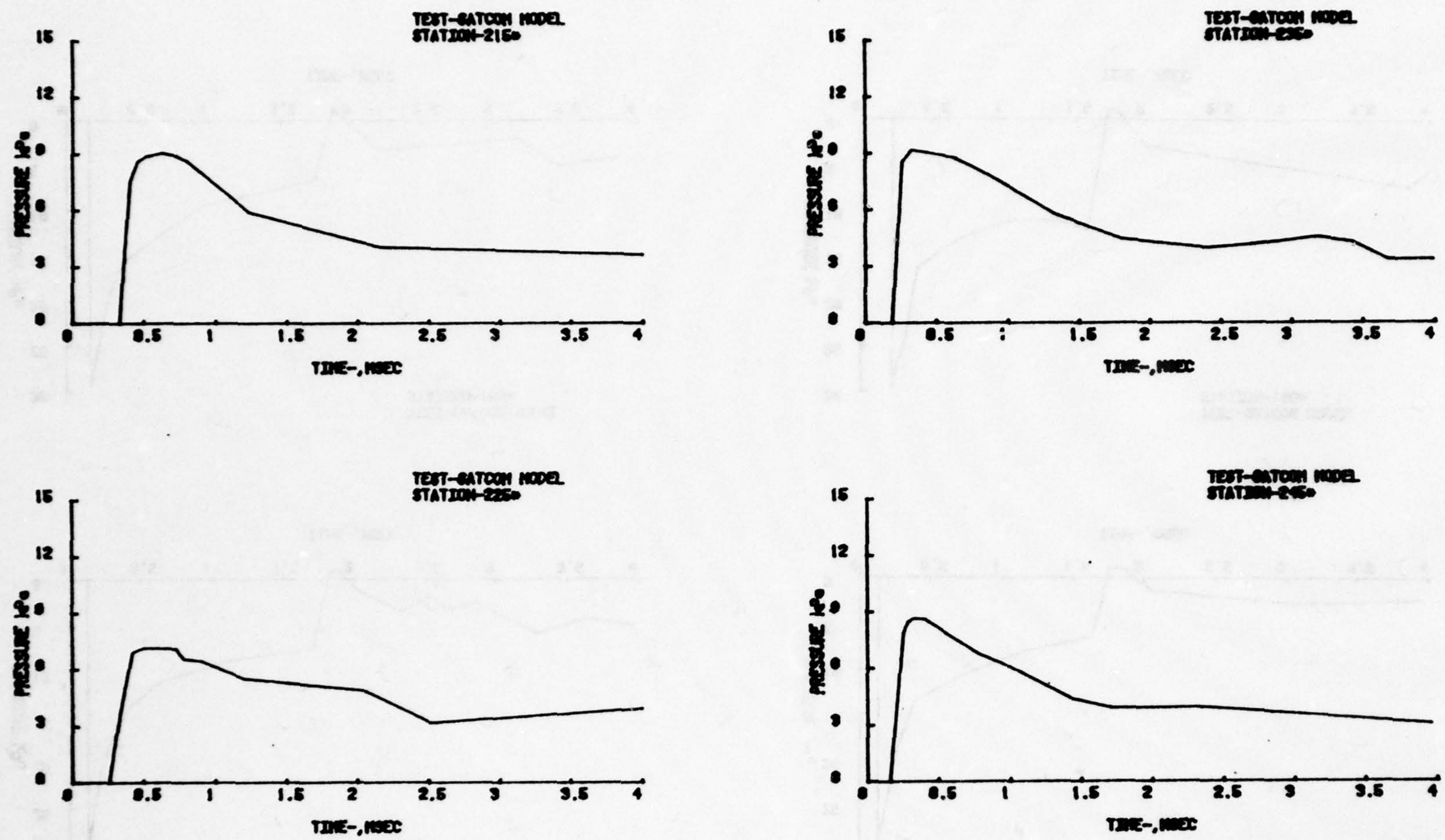


Figure 14. Constructed Pressure Histories, Rear Surface Position 5*

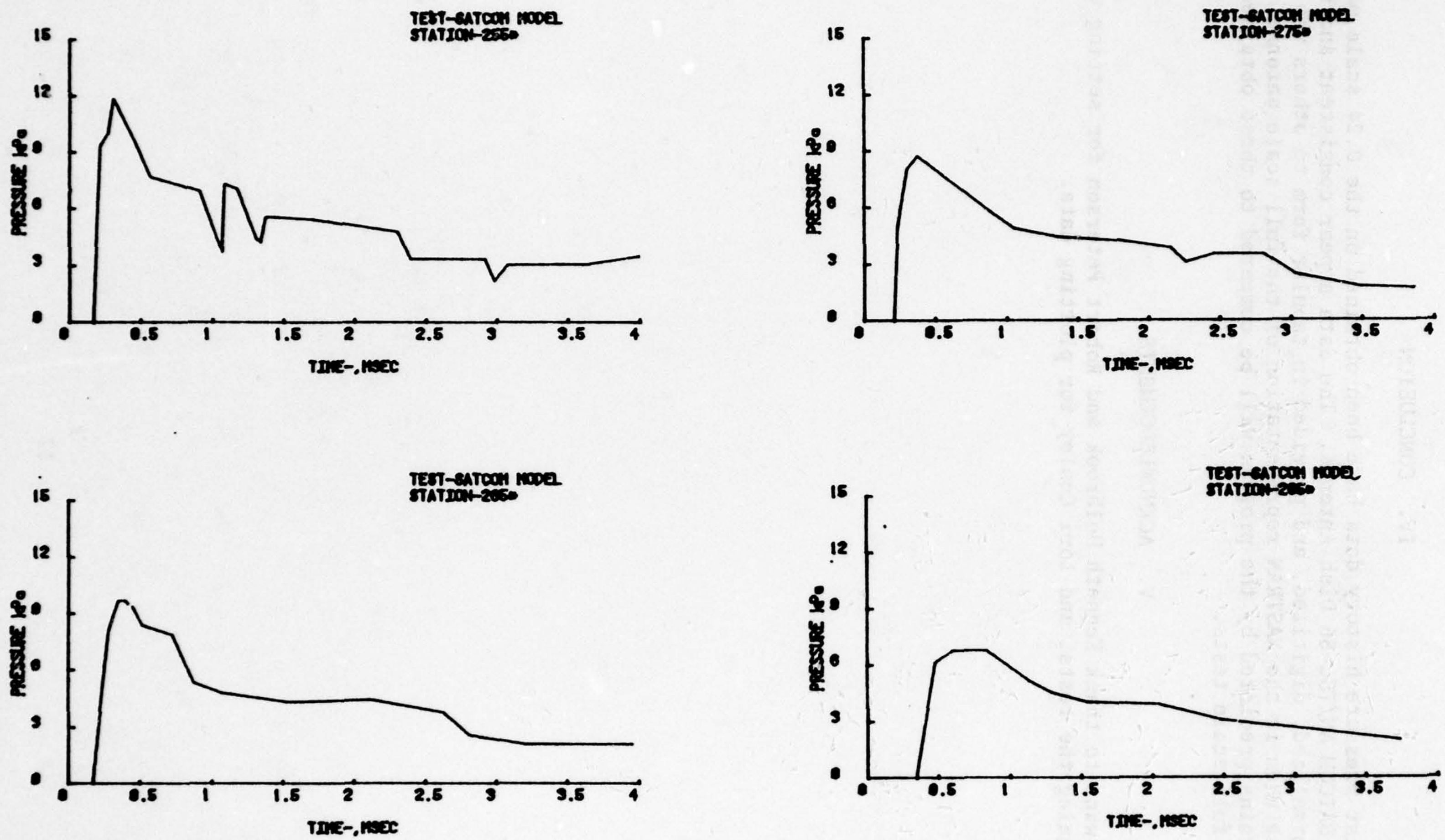


Figure 14 (Continued). Constructed Pressure Histories, Rear Surface Position 5*

IV. CONCLUSION

Blast pressure history data have been obtained on the 0.24 scale model of the SATCOM AN/TSC-86 Dish Antenna. The data appear consistent and have been normalized, digitized, and provided in tabular form to others who will use them in the NASTRAN representation of the full scale antenna. The strains predicted by the program will be compared to those obtained in the full scale tests.

V. ACKNOWLEDGEMENTS

We want to thank Kenneth Holbrook and Robert Peterson for setting up and running the tests, and Lori Conley for plotting data.

DISTRIBUTION LIST

No. of Copies	Organization
12	Commander Defense Documentation Center ATTN: DDC-TCA Cameron Station Alexandria, VA 22314
4	Director of Defense Research & Engineering ATTN: DD/TWP DD/S&SS DD/I&SS AD/SW Washington, DC 20301
2	Assistant to the Secretary of Defense (Atomic Energy) ATTN: Document Control Donald R. Cotter Washington, DC 20301
3	Director Defense Advanced Research Projects Agency ATTN: Tech Lib NMRO PMO 1400 Wilson Boulevard Arlington, VA 22209
1	Director Weapons Systems Evaluation Gp ATTN: Document Control Washington, DC 20305
1	Director Defense Communications Agency ATTN: Code 930 Washington, DC 20305
5	Director Defense Intelligence Agency ATTN: DT-1C DT-7D, E.O. Farrell DT-2, Wpns & Sys Div Technical Library DI-7E Washington, DC 20301
9	Director Defense Nuclear Agency ATTN: STSI/Archives SPAS/Mr. J. Moulton STSS/Dr. E. Sevin (2 cys) STVL/Dr. La Vier RATN/Mr. Rubenstein DDST/Mr. P. Haas STTL/Tech Lib (2 cys) Washington, DC 20305
2	Commander Field Command, DNA ATTN: FCPR FCTMOF Kirtland AFB, NM 87115
1	Commander Field Command, DNA Livermore Branch ATTN: FCPRL P. O. Box 808 Livermore, CA 94550
2	Director Defense Civil Preparedness Agency ATTN: Mr. George Sisson/RF-SR Technical Library Washington, DC 20301
3	Director Joint Strategic Target Planning Staff, JCS ATTN: Sci & Tech Info Lib JLTW-2 DOXT Offutt AFB Omaha, NB 68113
1	Director National Security Agency ATTN: E. F. Butala, R15 Fort George G. Meade, MD 20755

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST, N. Klein 5001 Eisenhower Avenue Alexandria, VA 22333
2	Commander US Army Materiel Development and Readiness Command ATTN: W. H. Hubbard Technical Library 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Aviation Research and Development Command ATTN: DRSAV-E P. O. Box 209 St. Louis, MO 63166
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035
6	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L DRDEL-SA W. S. McAfee R. Freiberg DELSD-EI, J. Roma DELSD-EM A. Sigismondi C. Goldy Fort Monmouth, NJ 07703
1	Commander US Army Communications Rsch and Development Command ATTN: DRDCO-SGS Fort Monmouth, NJ 07703
2	Commander US Army Missile Materiel Readiness Command ATTN: DRSMI-AOM DRSMI-XS/Ch Scientist Redstone Arsenal, AL 35809
1	Commander US Army Missile Research and Development Command ATTN: DRDMI-R Redstone Arsenal, AL 35809
1	Commander US Army Tank Automotive Research & Development Cmd ATTN: DRDTA-UL Warren, MI 48090
1	Commander US Army Mobility Equipment Research & Development Cmd ATTN: DRDME-RI, Dr. K. Oscar Fort Belvoir, VA 22060
5	Commander US Army Armament Research and Development Command ATTN: DRDAR-LCN-F Mr. Warren Reiner DRDAR-TSS (2 cys) P. Angelotti (2 cys) Dover, NJ 07801

DISTRIBUTION LIST

No. of Copies	Organization
2	Commander US Army Watervliet Arsenal ATTN: DRDAR-LCB-TL Watervliet, NY 12189
1	Commander US Army Armament Materiel Readiness Command ATTN: DRSAR-LEP-L, Tech Lib Rock Island, IL 61299
5	Commander US Army Harry Diamond Labs ATTN: DRXDO-TI/012 DRXDO-NP DRXDO-RBH, P.A.Caldwell DELHD-RBA, J. Rosado 2800 Powder Mill Road Adelphi, MD 20783
3	Commander US Army Materials and Mechanics Research Center ATTN: Technical Library John Mescall Richard Shea Watertown, MA 02172
2	Commander US Army Natick Research and Development Command ATTN: DRXRE, Dr. D. Sieling DRXNM-UE Arthur Johnson Natick, MA 01762
1	Commander US Army Foreign Science and Technology Center ATTN: Rsch & Concepts Branch 220 Seventh Street, NE Charlottesville, VA 22901
1	Commander US Army Training and Doctrine Command ATTN: ATCD-SA, Mr. Oscar Wells Fort Monroe, VA 23651
2	Director US Army TRADOC Systems Analysis Activity ATTN: LTC John Hesse ATAA-SL, Tech Lib White Sands Missile Range NM 88002
2	Commander US Army Nuclear Agency ATTN: ACTA-NAW Technical Library 7500 Backlick Rd, Bldg. 2073 Springfield, VA 22150
1	Commander US Army Combined Arms Combat Developments Activity ATTN: ATCA-CO, Mr. L.C.Pleger Fort Leavenworth, KS 66027
1	Commander US Army Engineering Center ATTN: ATSEN-SY-L Fort Belvoir, VA 22060
1	Commander US Army Logistics Center ATTN: ATCL-SCA Mr. Robert Cameron Fort Lee, VA 23801
1	Interservice Nuclear Weapons School ATTN: Technical Library Kirtland AFB, NM 87115

DISTRIBUTION LIST

No. of Copies	Organization
2	HQDA (DAMA-AR; NCL Div) Washington, DC 20310
2	Deputy Chief of Staff for Operations and Plans ATTN: Technical Library Dir of Chemical and Nuclear Operations Department of the Army Washington, DC 20310
2	Office, Chief of Engineers Department of the Army ATTN: DAEN-MCE-D DAEN-RDM 890 S. Pickett Street Alexandria, VA 22304
2	Director US Army BMD Advanced Technology Center ATTN: CRDABH-X CRDABH-S Huntsville, AL 35807
1	Commander US Army BMD System Command ATTN: BMDSC-TFN/N.J. Hurst P. O. Box 1500 Huntsville, AL 35807
1	Program Manager US Army BMD Program Office ATTN: John Shea 5001 Eisenhower Avenue Alexandria, VA 22333
1	Commander US Army Research Office P. O. Box 12211 Research Triangle Park NC 27709
5	Commander US Army Engineer Waterways Experiment Station ATTN: Technical Library William Flathau John N. Strange Guy Jackson Leo Ingram P. O. Box 631 Vicksburg, MS 39180
1	Division Engineer US Army Engineering Division Ohio River ATTN: Docu Cen P. O. Box 1159 Cincinnati, OH 45201
1	Division Engineer US Army Engineering Division ATTN: HNDSE-R, M. M. Dembo Huntsville Box 1600 Huntsville, AL 35804
1	Chief of Naval Material ATTN: MAT 0323 Department of the Navy Arlington, VA 22217
1	Chief of Naval Operations ATTN: OP-03EG OP-985F Department of the Navy Washington, DC 20350
1	Chief of Naval Research ATTN: N. Perrone Department of the Navy Washington, DC 20360
3	Director Strategic Systems Projects Ofc ATTN: NSP-43, Tech Lib NSP-273 NSP-272 Department of the Navy Washington, DC 20360

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander Naval Electronic Systems Cmd ATTN: PME 117-21A Washington, DC 20360
3	Commander Naval Facilities Eng. Command ATTN: Code 03A Code 04B Technical Library Washington, DC 20360
2	Commander Naval Sea Systems Command ATTN: ORD-91313 Library Code 03511 Department of the Navy Washington, DC 20362
2	Commander Naval Ships Engineering Ctr ATTN: Technical Library NSEC 6105G Hyattsville, MD 20782
1	Commander David W. Taylor Naval Ship Research & Development Ctr ATTN: Lib Div, Code 522 Bethesda, MD 20084
1	Commander Naval Surface Weapons Center ATTN: DX-21, Library Br. Dahlgren, VA 22448
3	Commander Naval Surface Weapons Center ATTN: Code WA501/Navy Nuclear Programs Office Code WX21/Tech Lib Code 240/J. Petes Silver Spring, MD 20910
1	Commander US Naval Weapons Center ATTN: Code 533, Tech Lib China Lake, CA 93555
2	Commander Naval Ship Research and Development Ctr Facility Underwater Explosions Rsch Division ATTN: Code 17/W.W. Murray Technical Library Portsmouth, VA 23709
2	Commander Naval Weapons Evaluation Facility ATTN: Document Control R. Hughes Kirtland AFB Albuquerque, NM 87117
4	Officer-in-Charge Civil Engineering Laboratory Naval Construction Btn Ctr ATTN: Stan Takahashi R. J. Odello John Crawford Technical Library Port Hueneme, CA 93041
2	Commander Naval Research Laboratory ATTN: Code 2027, Tech Lib Code 8440, F. Rosenthal Washington, DC 20375
1	Superintendent Naval Postgraduate School ATTN: Code 2124/Tech Rpts Lib Monterey, CA 93940
2	HQ USAF (IN; PRE) Washington, DC 20330

DISTRIBUTION LIST

No. of Copies	Organization
2	AFSC (DLCAW; Tech Lib) Andrews AFB Washington, DC 20331
2	ADTC (ADBRL-2; Tech Lib) Eglin AFB, FL 32542
2	AFATL (ATRD, R. Brandt) Eglin AFB, FL 32542
2	RADC (EMTLD/Docu Lib; EMREC/R. W. Mair) Griffiss AFB, NY 13340
1	AFWL/SUL Kirtland AFB, NM 87117
1	AFWL/DE-I Kirtland AFB, NM 87117
1	AFWL/DEX Kirtland AFB, NM 87117
1	AFWL/R. Henny Kirtland AFB, NM 87117
1	AFWL/DEV, M. A. Plamondon Kirtland AFB, NM 87117
2	Commander-in-Chief Strategic Air Command ATTN: NRI-STINFO Lib XPFS Offutt AFB, NB 68113
2	ADC (XP; XPQDQ) Wright-Patterson AFB, OH 45433
1	AFIT (Lib Bldg 640, Area B) Wright-Patterson AFB, OH 45433
1	AFML/LLN, Dr. T. Nicholas Wright-Patterson AFB, OH 45433
1	ASD (Tech Lib) Wright-Patterson AFB, OH 45433

No. of Copies	Organization
4	FTD (TDFBD; TDPMG; ETET, CPT R.C. Husemann; TD-BTA,Lib) Wright-Patterson AFB, OH 45433
1	Director US Bureau of Mines ATTN: Technical Library Denver Federal Center Denver, CO 80225
1	Director US Bureau of Mines Twin Cities Research Center ATTN: Technical Library P. O. Box 1660 Minneapolis, MN 55111
1	US Energy Research and Development Administration Division of Headquarters Svcs ATTN: Doc Control for Classified Tech Lib Library Branch G-043 Washington, DC 20545
1	US Energy Research and Development Administration Albuquerque Operations Office ATTN: Doc Control for Tech Lib P. O. Box 5400 Albuquerque, NM 87115
1	US Energy Research and Development Administration Nevada Operations Office ATTN: Doc Control for Tech Lib P. O. Box 14100 Las Vegas, NV 89114
5	Director Lawrence Livermore Laboratory ATTN: L. W. Woodruft/L-96 Tech Info Dept L-3 D. M. Norris/L-90 Ted Butkovich/L-200 J. R. Hearst/L-205 P. O. Box 808 Livermore, CA 94550

DISTRIBUTION LIST

No. of Copies	Organization
4	Director Lawrence Livermore Laboratory ATTN: Jack Kahn/L-7 J. Carothers/L-7 Robert Schock/L-437 R. G. Dong/L-90 P. O. Box 808 Livermore, CA 94550
4	Director Los Alamos Scientific Lab ATTN: Doc Control for Reports Lib R. A. Gentry G. R. Spillman Al Davis Los Alamos, NM 87544
1	Director National Aeronautics and Space Administration Scientific and Technical Information Facility P. O. Box 8757 Baltimore/Washington International Airport MD 21240
3	Aerospace Corporation ATTN: Tech Info Svcs (2 cys) P. N. Mathur P. O. Box 92957 Los Angeles, CA 90009
1	Agbabian Associates ATTN: M. Agbabian 250 North Nash Street El Segundo, CA 90245
1	Analytic Services, Inc. ATTN: George Hesselracher 5613 Leesburg Pike Falls Church, VA 22041

No. of Copies	Organization
1	Applied Theory, Inc. ATTN: John G. Trulio 1010 Westwood Boulevard Los Angeles, CA 90024
1	Artec Associates, Inc. ATTN: Steven Gill 26046 Eden Landing Road Hayward, CA 94545
1	AVCO ATTN: Res Lib A830, Rm 7201 201 Lowell Street Wilmington, MA 01887
1	The BDM Corporation ATTN: Richard Hensley P. O. Box 9274 Albuquerque International Albuquerque, NM 87119
2	The Boeing Company ATTN: Aerospace Library R. H. Carlson P. O. Box 3707 Seattle, WA 98124
1	Brown Engineering Co., Inc. ATTN: Manu Patel Cummings Research Park Huntsville, AL 35807
2	California Research and Technology, Inc. ATTN: Ken Kreyenhagen Technical Library 6269 Variel Avenue Woodland Hills, CA 91364
1	Calspan Corporation ATTN: Tech Library P. O. Box 235 Buffalo, NY 14221

DISTRIBUTION LIST

No. of Copies	Organization
1	Civil/Nuclear Systems Corporation ATTN: Robert Crawford 1200 University N.E. Albuquerque, NM 87102
1	EG&G, Incorporated Albuquerque Division ATTN: Technical Library P.O. Box 10218 Albuquerque, NM 87114
1	The Franklin Institute ATTN: Zemons Zudans 20th Street and Parkway Philadelphia, PA 19103
1	General American Trans Corporation General American Research Division ATTN: G. L. Neidhardt 7449 N. Natchez Avenue Niles, IL 60648
1	General Electric Company-TEMPO ATTN: DASIAC P.O. Drawer QQ Santa Barbara, CA 93102
2	Hazeltine Corp. ATTN: Carl Meinen Greenlawn, NY 11740
1	J. H. Wiggins Co., Inc. ATTN: John Collins 1650 South Pacific Cost Highway Redondo Beach, CA 90277
6	Kaman Avidyne ATTN: Dr. N. P. Hobbs (4 cys) Mr. S. Criscione Mr. John Calligeros 83 Second Avenue Northwest Industrial Park Burlington, MA 01830
3	Kaman Sciences Corporation ATTN: Library P. A. Ellis F. H. Shelton 1500 Garden of the Gods Road Colorado Springs, CO 80907
1	Lockheed Missiles & Space Co. ATTN: Technical Library P.O. Box 504 Sunnyvale, CA 94088
2	Martin Marietta Aerospace Orlando Division ATTN: G. Fotieo Mail Point 505, Craig Luongo P.O. Box 5837 Orlando, FL 32805
3	McDonnell Douglas Astronautics Corporation ATTN: Robert W. Halprin Mr. C. Gardiner Dr. P. Lewis 5301 Bolsa Avenue Huntington Beach, CA 92647
2	Merritt Cases, Inc. ATTN: J. L. Merritt Technical Library P.O. Box 1206 Redlands, CA 92373
1	Meteorology Research, Inc. ATTN: W. D. Green 454 West Woodbury Road Altadena, CA 91001
1	The Mitre Corporation ATTN: Library P.O. Box 208 Bedford, MA 01730

DISTRIBUTION LIST

No. of Copies	Organization
2	Pacifica Technology ATTN: G. Kent R. Bjork P. O. Box 148 Del Mar, CA 92014
4	Physics International Corp. ATTN: E. T. Moore Dennis Orphal Coye Vincent F. M. Sauer 2700 Merced Street San Leandro, CA 94577
4	Physics International Corp. ATTN: Robert Swift Charles Godfrey Larry A. Behrmann Tech Library 2700 Merced Street San Leandro, CA 94577
8	R&D Associates ATTN: Dr. H. L. Brode Dr. Albert L. Latter C. P. Knowles William B. Wright Jerry Carpenter Sheldon Schuster J. G. Lewis Technical Library P. O. Box 9695 Marina del Rey, CA 90291
1	The Rand Corporation ATTN: C. C. Mow 1700 Main Street Santa Monica, CA 90406
1	Sandia Laboratories Livermore Laboratory ATTN: Docu Control for Tech Lib P. O. Box 969 Livermore, CA 94550

No. of Copies	Organization
6	Sandia Laboratories ATTN: Docu Control for 3141 Sandia Rpt Collection A. J. Chaban M. L. Merritt L. J. Vortman W. Roherty L. Hill Albuquerque, NM 87115
1	Science Applications, Inc. ATTN: Technical Library P. O. Box 3507 Albuquerque, NM 87110
2	Science Applications, Inc. ATTN: R. Seebaugh John Mansfield 1651 Old Meadow Road McLean, VA 22101
1	Science Applications, Inc. 8201 Capwell Drive Oakland, CA 94621
2	Science Applications, Inc. ATTN: Technical Library Michael McKay P. O. Box 2351 La Jolla, CA 92038
4	Systems, Science & Software ATTN: Donald R. Grine Ted Cherry Thomas D. Riney Technical Library P. O. Box 1620 La Jolla, CA 92037
3	Terra Tek, Inc. ATTN: Sidney Green Technical Library A. H. Jones 420 Wakara Way Salt Lake City, UT 84108

DISTRIBUTION LIST

No. of Copies	Organization
2	Tetra Tech, Inc. ATTN: Li-San Hwang Technical Library 630 North Rosemead Blvd. Pasadena, CA 91107
7	TRW Systems Group ATTN: Paul Lieberman Benjamin Sussholtz Norm Lipner William Rowan Jack Farrell Pravin Bhutta Tech Info Ctr/S-1930 One Space Park Redondo Beach, CA 92078
1	TRW Systems Group ATTN: Greg Hulcher San Bernardino Operations P. O. Box 1310 San Bernardino, CA 92402
2	Union Carbide Corporation Holifield National Laboratory ATTN: Doc Control for Tech Library Civil Defense Research Proj. P. O. Box X Oak Ridge, TN 37830
1	Universal Analytics, Inc. ATTN: E. I. Field 7740 W. Manchester Blvd. Playa del Rey, CA 90291
1	Weidlinger Assoc. Consulting Engineers ATTN: M. L. Baron 110 East 59th Street New York, NY 10022
1	Westinghouse Electric Company Marine Division ATTN: W. A. Votz Hendy Avenue Sunnyvale, CA 94008
2	Battelle Memorial Institute ATTN: Technical Library R. W. Klingesmith 505 King Avenue Columbus, OH 43201
1	California Institute of Technology ATTN: T. J. Ahrens 1201 E. California Blvd. Pasadena, CA 91109
2	Denver Research Institute University of Denver ATTN: Mr. J. Wisotski Technical Library P. O. Box 10127 Denver, CO 80210
3	IIT Research Institute ATTN: Milton R. Johnson R. E. Welch Technical Library 10 West 35th Street Chicago, IL 60616
2	Lovelace Foundation for Medical Education ATTN: Asst Dir of Research, D. Richmond Technical Library 5200 Gibson Blvd., SE Albuquerque, NM 87108

DISTRIBUTION LIST

No. of Copies	Organization
1	Massachusetts Institute of Technology Aeroelastic and Structures Research Laboratory ATTN: Dr. E. A. Witmer Cambridge, MA 02139
2	Southwest Research Institute ATTN: Dr. W. E. Baker A. B. Wenzel 8500 Culebra Road San Antonio, TX 78206
2	Stanford Research Institute ATTN: Dr. G. R. Abrahamson Carl Peterson 333 Ravenswood Avenue Menlo Park, CA 94025
1	University of Dayton Industrial Security Super. KL-505 ATTN: H. F. Swift 300 College Park Avenue Dayton, OH 45409
1	University of Illinois Consulting Engineering Services ATTN: Nathan M. Newmark 1211 Civil Engineering Bldg. Urbana, IL 61801

No. of Copies	Organization
2	The University of New Mexico The Eric H. Wang Civil Engineering Research Facility ATTN: Larry Bickle Neal Baum University Station Box 188 Albuquerque, NM 87131
2	Washington State University Administration Office ATTN: Arthur Miles Hohorf George Duval Pullman, WA 99163

Aberdeen Proving Ground

Dir, USAMSAA
ATTN: Dr. J. Sperrazza
Mr. R. Norman, GWD

Cdr, USATECOM
ATTN: DRSTE-SG-H